BIOTA TRANSFER STUDY

DEVILS LAKE FLOOD DAMAGE REDUCTION ALTERNATIVES

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EXECUTIVE SUMMARY

INTRODUCTION

Peterson Environmental Consulting, Inc. (PEC) has been retained by the U. S. Army Corps of Engineers (USACE) St. Paul District to prepare a Biota Transfer Ecological Risk Assessment regarding alternatives to reduce flood damage in the Devils Lake Basin, North Dakota. Devils Lake and its watershed, located in east central North Dakota, lie within the western part of the Red River Basin of the Hudson Bay drainage. Water levels in Devils Lake fluctuate erratically and have periodically resulted in protracted lake-level increases to the point where surface waters overflow into the Sheyenne River to the south. Overflow events have been rare and have been separated by long periods during which the basin functions as a closed system. No natural overflow events have occurred in recorded history. Since 1940 when the lake was nearly dry, precipitation has consistently exceeded evaporation, and the lake has grown much larger and deeper. Devils Lake is now about 120,000 acres in size, and 24 feet deeper than it was in 1993 and has caused severe damage to public infrastructure, houses, and farmland.

Two constructed-outlet alternatives are under consideration, both if which would release water from West Bay of Devils Lake to the Sheyenne River during a May 1 through November 30 operating window. Operations would cease if the elevation of Devils Lake drops below 1435 feet above sea level (fASL). Under the 300 cubic feet per second (cfs) Constrained Outlet alternative, discharge of Devils Lake water would be constrained by flow and water quality parameters. The 480 cfs Unconstrained Outlet alternative would release Devils Lake water through the same constructed outlet with no constraints. This report also considers a No Action (natural spill) alternative assumes that the level of Devils Lake will rise until it naturally spills from Stump Lake through the Tolna Coulee to the Sheyenne River downstream of Warwick, ND.

The objectives of this study are summarized as follows:

1. Identify biota of concern, understand their life history, and determine the physical and biological mechanisms by which the project would affect their spread.
2. Determine the ecological, economic, and natural resource consequences that could ensue if the identified biota were to be spread by the project.
3. Identify measures to reduce uncertainty regarding the risk of any adverse ecological, economic and natural resource impacts from the transfer of damaging biota to the Red River basin.
4. Determine if any identified damages are preventable and avoidable by alternatives or modifications of the proposal, develop a plan of action regarding the response to the appearance of damaging biota in Devils Lake if the project is operating, and assess the feasibility of this plan to prevent downstream movement of the biota.
5. Present findings in a manner that will allow the unavoidable ecological, economic, and natural resource risks and damages associated with transfer of damaging biota to the Red River basin to be readily integrated with and compared to other adverse and beneficial impacts of the outlet, to facilitate an accurate assessment of overall project benefit-cost and feasibility indicators.

The first phase of the ecological risk assessment process is to identify "Potential Biota of Concern" (PBOC), characterize their life histories and determine the physical and biological mechanisms by which the project would affect their spread. PBOC are defined as biota that could directly or indirectly cause environmental and economic damage in the Red River Basin (including North Dakota, Minnesota, and Canada). The second phase is to identify which PBOC species are of particular concern because of their life history characteristics, invasiveness, and the potential magnitude of downstream impacts. These are referred to as "Biota for Risk Assessment" (BRA) and are subject to a more detailed assessment to determine magnitude of potential impacts and extent of risk as a consequence of operation of a constructed outlet.

METHODS

The ecological risk assessment process entailed a series of iterative steps by which: (1) comprehensive lists of species present in the Devil's Lake and Red River basins were developed, (2) candidate potential biota of concern (PBOC) were identified from the comparison of these lists, (3) the biological characteristics of candidate PBOC species were investigated to determine whether they should be retained on the final list of PBOC, (4) from the final PBOC list, a list of biota for risk assessment (BRA) was developed based on existing pathways by which species might travel between the Devils Lake and Red River basins, their known geographic ranges, and many biological characteristic that might make them problematic in a new environment, and (5) a risk assessment for any BRA species. Because numerous species required analysis and the distinctions between PBOC and BRA were not always clear, a decision-tree was developed to standardize the process.

Development of Comprehensive Species Lists

All sources of existing information on the biota of the Devils Lake and Red River basins were sought. This step involved seeking, procuring, and examining written sources of information (published and non-published), and seeking and consulting experts on Devils Lake and Red River basin biota and related issues. The initial literature search started with the sources listed in the "Annotated Bibliography on Aquatic Biota of Devils Lake, Sheyenne River, Red River of the North, and Lake Winnipeg" (Schmidt 1999) provided by the USACE. Additional literature search methods included: (1) searches of web-based biological information sources, (2) searches for relevant journal articles using electronic databases (e.g. Biological Abstracts), (3) review of the Literature Cited sections in key sources and (4) the use of internet search engines to find current unpublished information on biota. Experts from universities and federal, state, and provincial agencies were consulted.

While this study was to be based on existing information, some field observations were made by study team members during two visits to the Devils Lake basin. Because published information on vascular plants specific to the Devils Lake basin was almost non-existent, the study team's field observations were included in the analysis. During the visits, team members also met with local flora experts and reviewed unpublished records of flora from the study region.

Candidate Potential Biota of Concern (PBOC)

Lists of "Candidate" PBOC species were constructed for vascular plants, algae, invertebrates (including free-living protozoa), fishes, fish parasites, and fish pathogens. All original sources were obtained and carefully reviewed for species occurrence records. Taxonomic databases were used to record taxonomic history and update any species for which taxonomic names had been changed. When alternative names for the same taxon were encountered in the literature, they were included in the appropriate tables.

The separate effort to find information on vascular plants began with the construction of a list of all species classified by Reed (1988) as OBL (obligatory aquatic species) or FACW (facultative wetland species) and known to occur in North Dakota, according to regional flora lists. This list was compared to published regional flora, unpublished sources provided by local experts, and to the species list developed during the site visit to determine which species were present in the Devils Lake basin and which were in the Red River basin. Several species were automatically added to the Candidate PBOC list, either because they were designated as prohibited or regulated invasive species by government authorities or were specifically named in the Statement of Work for the study.

Final PBOC List

To determine which taxa should be included on the final PBOC list, the pool of Candidate species was first divided into "PBOC" and "non-PBOC". This distinction was made based on location records for each taxon, and on information about their dispersal abilities and distribution. The Statement of Work calls for species common in the Red River basin to be distinguished from those with only limited distribution within the basin. However, the temporal and spatial coverage of existing data collected from the Red River were generally inadequate to allow such a distinction to be made. As a result, only a presence/absence criterion could be applied. All candidate species recorded from Red River basin sites were classified as "non-PBOC". This was considered reasonable because all Red River basin data were collected from Lake Winnipeg, the Red River mainstem, or the Sheyenne River, rather than from minor tributaries or isolated waters in remote locales that would suggest highly localized distributions. Taxa with obvious existing inter-basin pathways were also considered “non-PBOC” (e.g. flying insects). The remaining taxa comprised the final PBOC list. All known species considered “non-PBOC" have been were listed with references to literature sources documenting their occurrence in the Red River basin.

Biota for Risk Assessment (BRA)

Once the PBOC list was compiled, it was necessary to determine which of these species should be carried forward into a full risk assessment process. Where available, more detailed information on the biological characteristics of each taxon was compiled and analyzed in light of existing and predicted habitats and inter-basin transfer pathways. Species-specific life history accounts were prepared as the foundation for this additional analysis. Each species account included:

A. life history and life stages, geographical distribution, habitat requirements, and other relevant biological information;

B. body sizes at different life stages, detection methods, and possible detection problems;

C. mechanisms for movement and dispersal;

D. species' functions in ecosystem and potential effects of species' introduction to non-native systems.

Determinations regarding the likelihood of inter-basin transfer of PBOC species were based on assessments of: (1) existing Devils Lake habitats and PBOC species benefited by recent habitat changes, (2) existing interbasin transfer pathways, existing downstream habitats and (3) projected habitat alterations due to erosion/sedimentation, changes in flow volume/duration and modification of water chemistry. Based on the foregoing assessments, predictions were made regarding: (1) the likely impact of the project on PBOC species' relative abundances in communities they might invade or in which they already occur, (2) changes in individual species' ranges, and (3) changes in their potential invasiveness. Identified pathways for potential transfer were analyzed to determine whether they are subject to regulatory or physical control.

All collected information on PBOC species was analyzed and used as a basis for selection of species to be included on the final BRA List. The selection procedure was standardized by using a decision tree which initially classified all species as possible BRA, non-BRA, and provisional BRA. Provisional BRA were those species that had potential to cause downstream effects only if certain habitat changes also occurred. Possible BRA and Provisional BRA were analyzed further to attempt to fill gaps in knowledge remaining after the initial analyses. These more detailed analyses were used to determine which biota should be carried on for risk assessment, and which were considered very unlikely threats to downstream waters.

Risk Assessment of BRA Species

According to the Statement of Work, risk analysis procedures were to follow those described in CENR (1999). Many of the prescribed risk assessment tasks were completed during earlier steps in the analyses, so partial risk assessments were conducted for all PBOC species in the BRA-classification stage of the study. Certain species were found to be of sufficient concern to warrant more attention than required by the Statement of Work for non-BRA species, so these analyses were carried out with the intended purposes of the CENR (1999) and USEPA (1998) procedures kept in mind. This involved describing the potential risks posed by the species, and addressing concerns noted in the Statement of Work, such as the species invasiveness, its likely effects on downstream communities, the likelihood of the species spreading further downstream, and the likelihood of economic costs associated with the species. Finally, two species were retained for full risk analysis following the nonindigenous species example presented in CENR (1999).

RESULTS

Creation of Candidate PBOC List

Extensive searches produced relatively few information sources other than those listed in the USACE bibliography. Although fish and algae communities have been fairly well documented, data sources on other biota were relatively few and incomplete. Regional experts had little knowledge of Devils Lake biota, and most agreed that the biota of the Devils Lake and Red River basins had not been particularly well studied. The most complete record of Devils Lake biota was a very old account of the lake during a period of falling water level and increasing salinity.

Published information on plants of the basins was more scarce than data found for other biota. The separate investigation of vascular plants produced several sources of information among local experts and institutions, although none explicitly defined the flora of either basin.

Consultation of these sources plus site visits allowed team members to assemble a partial list of Candidate PBOC vascular plants.

Some published Devils Lake parasite information was found, but consultations and literature searches for records of Devils Lake basin fish pathogens produced no information. The lack of pathogen data was an area of concern, and field study is warranted because of the economic importance of fish diseases. However, it seemed unlikely that any pathogens would be confined to Devils Lake because, at one time or another, every major lake in the state has served as both source and destination of wild-caught fish for stocking, so natural barriers to fish pathogen transmission have been repeatedly circumvented by human actions.

The Candidate PBOC list included 527 algae, 353 plant species, 94 free-living protozoa taxa, 146 invertebrate taxa, 12 fishes, 8 fish parasites, and 1 avian pathogen (no fish pathogens or fungi were included). This was believed to be the most complete list of Devils Lake Basin biota that could be assembled based on authoritative information sources. However, this list must certainly have been incomplete because very many data gaps were found, and some taxa on the list may no longer exist in Devils Lake because its habitat conditions have changed dramatically since the earlier records were published.

Selection/Deselection of PBOC

To produce the PBOC list, deselections were made from the Candidate PBOC list based mainly on distribution criteria. Then, insects and water mites were deselected because of their obvious and very effective existing interbasin transfer mechanisms. These deselections produced a PBOC list of 387 taxa: 215 algae, 73 invertebrate taxa, 94 protozoa, 1 fish species, zero plants, 3 fish parasites, and 1 avian pathogen. Finally, the 42 automatically listed taxa were added to the 386 selected as PBOC, so the final PBOC list consisted of 429 taxa.

Data Gaps

Perhaps the most important finding of this study was the revelation of just how poorly the biota of the Devils Lake basin and (to a somewhat lesser extent) the Red River basin are known. Many Devils Lake taxa had to be selected as PBOC solely because no data could be found regarding their presence or absence in the Red River basin. The deficiencies in the available data could be summarized as problems of poor comparability of studies from each basin, and gaps in coverage.

Lack of comparability of Devils Lake basin and Red River basin data arose because: (1) studies were conducted in dissimilar habitats in the two basins, (2) sampling intensity differed between basins, (3) studies varied in taxonomic focus and (4) resolution, (5) studies were carried out widely separated in time, resulting in (6) studies being carried out under very different environmental conditions.

Coverage gaps found in the existing data included: (1) very poor coverage of the wide range of aquatic habitats found in each basin, (2) poor coverage of temporal changes that occur seasonally in aquatic communities, and (3) inconsistent coverage of biota groups. This last type of data gap was particularly obvious in the complete lack of data on Devils Lake basin fish pathogens, the poor coverage of fish parasites, the lack of vascular plant studies, and the near lack of studies on non-planktonic invertebrates in all waters of the basins in question, except Lake Ashtabula and Lake Winnipeg.

Biology and invasiveness of PBOC

Review of the biology and distributions of PBOC revealed that none of the taxa, other than automatically listed species, were known to be particularly invasive. None of the automatically listed exotic, invasive PBOC species were known to occur in the Devils Lake basin. The proposed outlet project could change downstream physical and chemical habitat parameters, but it was not apparent that these changes would dramatically enhance the invasiveness of any PBOC species.

Devils Lake habitats were found to be increasingly varied in response to water-level increases. The changes occurring in the lake are likely to favor the majority of species in the lake, but are increasing the similarity between Devils Lake habitats and downstream lentic habitats, thus reducing the magnitude of expected chemical chemical changes in the Sheyenne River and Lake Ashtabula. The increased freshening of Devils Lake water has caused many halophilic (salt-adapted) species to be increasingly confined to the more saline, eastern portions of the lake. These species, once the dominant forms in the lake, are likely to continue to be marginalized and limited to saline refuges far from the projected pump intake locations.

The question of biota transfer from Devils Lake to the Sheyenne River must involve consideration of the likelihood that Devils Lake species can already be transferred across the basin boundary by existing natural or anthropogenic means. Such transfers are considered common and effective for most PBOC taxa. Natural dispersal vectors likely to be important in the Devils Lake/Red River region are wind and vertebrate animals. Anthropogenic vectors are abundant and include recreational boats and trailers, baitfish transfer, and an active fish stocking program that has effected reciprocal transfers among many waters in the state.

Based on review of dispersal mechanisms of PBOC, and consideration of the topography and other conditions in the region, it was concluded that natural pathways between the basins are, and have been, effective means of biota transfer for a very long time. Almost all PBOC taxa were considered to already have adequate means of transfer such that the project would have little impact on their invasiveness. The project would certainly have the effect of transferring organisms from Devils Lake to the Sheyenne River, but it seems very unlikely that any such transfers would involve first-time introductions.

The greater concern was the possibility that downstream water chemistry changes would favor shifts in communities toward more salt-adapted and eutrophy adapted species compositions. Salinity changes would likely affect the Sheyenne River and Lake Ashtabula most, with effects much less substantial in the Red River due to dilution. Higher salinity and/or nutrient concentrations, however modest, could possibly tilt competitive balances toward new equilibria favoring more halophilic and/or eutrophication-indicator species. This is only a biota transfer concern to the extent that the outlet provides a new source of these species, enhancing the numbers already likely to be present in downstream habitats. In this case, the outlet would simply accelerate a process that would occur naturally.

Selection/Deselection of BRA

The large majority of PBOC were ultimately classified as "Non-BRA" species because they were found to be widespread in distribution, and/or able to disperse readily among water bodies. They were also found to have no history of being particularly invasive or of causing human-defined problems in their usual habitats. It is impossible to predict the effects of any species' new introduction to a system, as the history of past exotic species introductions clearly shows, but existing published information suggests that the species classified as Non-BRA are likely to be benign in the RRB.

Several PBOC taxa were retained for further analysis, including the fish parasites and certain species of nuisance algae. These further analyses determined that:

A. two of the three parasite species were, in fact, known to occur in the Red River basin, but had not been recorded in the published literature,

B. the one remaining parasite was very probably a very common parasite in the region that was misidentified by the single author who reported it,

C. two algae species had been associated with toxic algae blooms in the past, but more recent studies found their toxicity to be very low,

D. one algae species was from a genus known for damaging fish gills, but the species in question was not known to cause such problems,

E. one algae species was known to create toxic blooms, but further evidence suggested that it is very likely to already occur in the Red River basin waters, and that it is unlikely to be transferred through the outlet because it is a halophile and presently only found in eastern portions of Devils Lake.

Finally, two species were retained for full risk analysis: striped bass and Eurasian watermilfoil. Striped bass were introduced into Devils Lake in the past, but their continued presence there is doubtful. Nonetheless, the small possibility that a reproducing population exists in the lake poses some risk to the Sheyenne/Red River system and Lake Winnipeg. Eurasian watermilfoil, on the other hand, is not known to occur in Devils Lake, but a small population has been found in the Sheyenne River below Lake Ashtabula. Increased flows in the river resulting from an outlet would cause an increased risk of the species spreading downstream, though this risk is only incrementally greater than the already existing high risk of spread.

Conclusions and Recommendations

The conclusions of the study were that: (1) <u>based on all available information</u>, it appeared highly unlikely that downstream habitats would suffer substantially <u>as a result of biota transfer</u> caused by the Devils Lake outlet project, and (2) available information was inadequate to allow conclusive statements to be made regarding all aspects of biota transfer.

However, several concerns were considered worth noting.

A. The risk of striped bass transfer to downstream waters is considered very low, primarily because the species is not believed to be reproducing in Devils Lake. This belief should be confirmed or refuted with larval and juvenile fish surveys.

B. The outlet would only marginally increase the risk of downstream spread of Eurasian watermilfoil, which is highly likely to occur with or without an outlet.

C. Though unlikely to occur, transfer of significant concentrations of toxic algae could cause substantial problems downstream.

D. Salinity and nutrient changes to the Sheyenne River and Lake Ashtabula could cause community composition changes in these waters.

E. It is presently unknown whether any known exotic, invasive species are now present in Devils Lake.

Therefore it is recommended that: the known Eurasian watermilfoil population should be eradicated as soon as possible, chemical and algal monitoring programs should accompany the outlet project, fish pathogen should screening be implemented (already under way), and that surveys for the following invasive species (at minimum) should be carried out in Devils Lake before the outlet begins operation: striped bass juveniles, rusty crayfish, spiny water flea, zebra mussel, and Chinese mystery snail and relatives.

As secondary concerns, it is recommended that Devils Lake be monitored for species that are known to occur in the Red River basin, but are not known to have invaded the lake yet (e.g. Eurasian watermilfoil, curly-leaf pondweed), and that a boat ramp monitoring/public education program be implemented in North Dakota to attempt to minimize anthropogenic biota transfers.

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1. INTRODUCTION

1.1 BACKGROUND

Peterson Environmental Consulting, Inc. (PEC) has been retained by the U. S. Army Corps of Engineers (USACE) St. Paul District to prepare a Biota Transfer Ecological Risk Assessment regarding alternatives to reduce flood damage in the Devils Lake Basin, North Dakota. A number of downstream stakeholders have expressed concerns about the potential for the inter-basin transfer of exotic or invasive biota. Concerns have been expressed by federal, state and provincial governments, Indian tribes, First Nations and environmental groups in the United States and Canada. To address these concerns, the St. Paul District USACE has included the analysis of biota transfer issues as part of the Environmental Impact Statement for the flood reduction alternatives.

Devils Lake and its watershed, located in east central North Dakota, lie within the western part of the Red River Basin of the Hudson Bay drainage (Figure 1). Water storage in the basin is highly variable, depending on climate patterns, so water levels in Devils Lake fluctuate erratically. These fluctuations have occasionally included protracted lake-level increases to the point where surface waters overflow into the Sheyenne River to the south. An overflow has not occurred in recorded history so the basin usually functions as a closed system. The most recent extreme low water-level occurred in 1940 when the lake was essentially dry. Since 1940, precipitation has consistently exceeded evaporation, so the lake has stored increasing volumes of water, and its areal extent has undergone a large expansion. Devils Lake is now about 120,000 acres in size, and 24 feet deeper than it was in 1993. Severe flood damages to public infrastructure, homes, and farmland have ensued, and construction of an outlet to the Sheyenne River and thence to the Red River is proposed.

The alternatives considered in this report include two constructed-outlet alternatives and a no action alternative. Both constructed outlet alternatives would release water from West Bay of Devils Lake to the Sheyenne River during a May 1 through November 30 operating window. Operations would cease if the elevation of Devils Lake drops below 1435 feet above sea level (fASL). Under the 300 cubic feet per second (cfs) Constrained Outlet alternative, discharge of Devils Lake water would be constrained by flow and water quality parameters. The 480 cfs Unconstrained Outlet alternative would release Devils Lake water through the same constructed outlet with no constraints. The No Action (natural spill) alternative assumes that the level of Devils Lake will rise until it naturally spills from Stump Lake through the Tolna Coulee to the Sheyenne River downstream of Warwick, ND.

The objectives of this study are to:

1. Identify biota of concern, understand their life history, and determine the physical and biological mechanisms by which the project would affect their spread.
2. Determine the ecological, economic, and natural resource consequences that could ensue if the identified biota were to be spread by the project. Natural resource damages include, but are not limited to, damages to ecosystems and changes that decrease the utility of uses of resources, or increase the cost of utilizing these resources.

3. Identify measures to reduce uncertainty regarding risk of any adverse ecological, economic and natural resource impacts from transfer of damaging biota to the Red River basin.

4. Determine if any identified damages are preventable and avoidable by alternatives or modifications of the proposal, develop a plan of action regarding the response to the appearance of damaging biota in Devils Lake if the project is operating, and assess the feasibility of this plan to prevent downstream movement of the biota.

5. Present findings in a manner that will allow the unavoidable ecological, economic, and natural resource risks and damages associated with transfer of damaging biota to the Red River basin to be readily integrated with and compared to other adverse and beneficial impacts of the outlet, to facilitate an accurate assessment of overall project benefit-cost and feasibility indicators.

The first phase of the ecological risk assessment process is to identify "Potential Biota of Concern" (PBOC), characterize their life histories and determine the physical and biological mechanisms by which the project would affect their spread. PBOC are defined as biota that could directly or indirectly cause environmental and economic damage in the Red River Basin (including North Dakota, Minnesota, and Canada). Species have been listed as a PBOC if they; (1) are found in the Devils Lake Basin but are absent or of restricted distribution within the Red River basin, (2) have biological characteristics that suggest that they could cause environmental or economic damage if transferred between the two basins, and (3) the operation of an outlet from Devils Lake would potentially provide a mechanism or pathway for the species to move between basins.

The second phase is to identify which PBOC species are of particular concern because of their life history characteristics, invasiveness, and the potential magnitude of downstream impacts. These are referred to as "Biota for Risk Assessment" (BRA) and are subject to a more detailed assessment to determine magnitude of potential impacts and extent of risk as a consequence of operation of a constructed outlet. Full risk assessments involve the following steps.

1. Determine invasiveness of each BRA species with and without the project

2. Determine potential for BRA to harm species native to Red River basin

3. Address economic, ecological and natural resource costs of BRA transfer to Red River basin

4. Determine if there are methods available to reduce or eliminate identified risks

5. Determine if the application of elements of the National Invasive Species Management Plan would potentially reduce or eliminate identified risks

6. Develop a Monitoring Program for BRA Species Identified as Being Present in Devils Lake and Likely to Cause Unacceptable Impacts if Transported into the Red River Basin

7. Identify and Assess the Effectiveness of Existing Regulatory Programs in Preventing or Ameliorating Identified Risks

8. Identify and Assess the Effectiveness and Economic Feasibility of Potential Physical, Chemical or Biological Barriers that Could Prevent or Ameliorate Unacceptable Downstream Impacts

9. Identify and Assess the Effectiveness and Economic Feasibility of Operational Alternatives that Would Reduce or Eliminate Identified Risks
10. Describe Regulatory Mechanisms that Would Ensure Application of Effective and Feasible Mitigation Measures

1.2 TERMINOLOGY

Throughout this report, "DLB" (Devils Lake Basin) refers to the entire Devils Lake sub-basin of the Red River basin, and "RRB" (Red River Basin) refers to the entire basin drained by the Red River and its tributaries, standing waters within the basin (exclusive of the Devils Lake sub-basin), and Lake Winnipeg. "Downstream" refers more specifically to waters in the downstream flowpath of waters leaving the proposed outlet: the Sheyenne River, Red River mainstem, and Lake Winnipeg.

The Statement of Work that defined the parameters of the study used the term "species" in reference to all biota under consideration. However, in many cases the existing literature identified biota only to the genus level (or higher), so this report generally uses the terms "taxon" and "taxa" to encompass all biota under discussion, regardless of the taxonomic level to which they have been identified in the literature.

"Macrophyte" refers to large plants, and is typically interchangeable with "vascular plant" in aquatic literature. It is distinguished from the "algae", which includes photosynthesizing (thus "plant-like") organisms in the kingdom Protista (a.k.a. "Protoctista"), and to the Cyanobacteria (a.k.a. "blue-green algae" or "cyanophytes") in the kingdom Monera (a.k.a. "Eubacteria"). As applied to the Devils Lake and Red River basins in this study, "algae" includes species with differing growth forms: unicellular, colonial, and filamentous. The remaining members of the kingdom Protista are non-photosynthesizing (thus "animal-like"), and are commonly referred to as "Protozoa". "Algae" and "protozoa" are terms of convenience lacking taxonomic significance according to most present-day authors, but commonly used in the scientific literature because of their practical usefulness and functional meanings.

"Macroinvertebrate" refers to relatively large invertebrate animals retained in a standard sorting sieve with mesh openings of 500 µm ("micrometer" or "micron"), or 0.500 mm. "Meiofauna" and similar terms with the "meio" prefix refer to invertebrate animals of intermediate size that pass through a 500 µm mesh, but are retained on a 63 µm mesh. "Microbe", "microbiota" and similar terms refer to organisms smaller than meiobiota, typically bacteria, unicellular fungi and protists, and some very small invertebrate animals.

Habitat descriptors include "lotic" and "lentic", referring to flowing and standing waters, respectively. "Littoral" refers to water's edge habitats, usually from zero depth down to the depth limit of rooted plant establishment. "Limnetic", "open water", and "pelagic" commonly refer to areas deeper than the littoral zone, where the biota are suspended in the water column and are referred to as "plankton"; "zooplankton" are animals and "phytoplankton" are algae. Below these suspended biota are the "benthos": all organisms living on and among the bottom sediments of a water body, usually including those in the littoral zone.

2. METHODS

The ecological risk assessment process entailed a series of iterative steps by which: (1) comprehensive lists of species present in the Devils Lake and Red River basins were developed, and all Devils Lake biota were designated "Candidate" Potential Biota of Concern (PBOC), (2) from the Candidate PBOC, biota were selected for the final PBOC list by the comparison of DLB and RRB lists, (3) the biological characteristics of PBOC species were investigated to determine whether they should be retained for further analysis, (4) from the PBOC list, a list of biota for risk assessment (BRA) was developed based on existing pathways by which species might travel between the Devils Lake and Red River basins, their known geographic ranges, and many biological characteristic that might make them problematic in a new environment, and (5) a risk assessment for any BRA species was conducted.

Because many more taxa than expected required analysis and the distinctions between PBOC and BRA were not always clear, a decision-tree was developed to standardize the process:

Decision Tree for PBOC/BRA Selection:

1. FOR EACH CANDIDATE PBOC: Is the species an "automatically listed" species?
   YES -- **PBOC**, go to 3
   NO -- Go to 2
2. Does the species appear to be present in both the DLB and RRB?
   YES -- **not PBOC**
   NO -- **PBOC**, go to 4
3. FOR EACH AUTOMATIC PBOC: Is the species present in the DLB?
   YES -- Go to 4
   NO -- **not BRA**, species is not in DLB
4. Does literature indicate that the species has substantial existing pathways from the DLB to the RRB?
   YES -- go to 5
   NO -- go to 6
5. Is the RRB within or adjacent to the known geographic range of the species?
   YES -- go to 7
   NO -- **BRA**, species is exotic in the region; project could enhance existing pathways
6. Is the RRB completely within the known geographic range of the species?
   YES -- go to 7
   NO -- **possible BRA -** more analysis needed
7. Is species probably excluded from RRB by biotic or abiotic environmental factors?
   YES -- **possible provisional BRA**, invasion depends on habitat changes; more analysis needed
   NO -- go to 8
8. Is species likely to cause problems if it invades RRB under present habitat conditions?
   YES -- **possible BRA -** more analysis needed
   NO -- **not BRA**
9. Is species likely to be transferred by project?
   YES -- **BRA**
   NO -- **not BRA**

2.1 Selection of Potential Biota of Concern (PBOC)

2.1.1 Step 1: Creation of Candidate PBOC List

"Candidate" PBOC include all biota that have been reported as occurring in the Devils Lake basin at any time. This group represents all species that could be transferred into the Sheyenne River by the proposed outlet. This list was the necessary precursor to the PBOC list, so care was taken to include all species whose occurrence was reported by reliable sources. Next, certain species with known invasive tendencies or other problematic characteristics were added, whether reported from DLB or not. The identities of these species were provided in the Statement of Work.

The construction of the "Candidate" list proceeded as described below, but the process was complex and iterative because new information sources and additional species information were found throughout the study period. The process was conceptually organized into the following tasks:

A. Collect all available existing information on species occurrences within the DLB and RRB. All sources of information on the biota of the Devils Lake and Red River basins were sought. For the most part, this step involved seeking, procuring, and examining written sources of information (published and non-published), and seeking and consulting experts on DLB/RRB biota and related issues. Consultations with experts were generally made via e-mail in order to generate a written record, but in some cases these consultations were followed up with telephone contacts.

   According to the Statement of Work this study was to be based on existing information and additional field work was not to be conducted. However, because published information on vascular plants of the DLB was almost non-existent, some field observations were made by study team members during two site visits. This information has been included in this study but does not represent a systematic survey of plant species. During the visits, team members also met with local flora experts and reviewed unpublished records of flora from the study region.

   The initial literature search started with the sources listed in the "Annotated Bibliography on Aquatic Biota of Devils Lake, Sheyenne River, Red River of the North, and Lake Winnipeg" (Schmidt 1999) provided by the USACE. Copies of the referenced material were collected and studied to find additional useful references cited in these papers. Additional literature searches were used in an attempt to find all relevant material. Search methods included: searches of web-based biological information sources, such as the Integrated Taxonomic Information System; searches for journal articles using electronic databases (e.g. Biological Abstracts); searches of literature cited sections in key articles or sources; and the use of internet search engines to find current unpublished information on biota.

   All types of biota were addressed in this study. However, because pathogens and parasites of fishes have been previously identified as a particular area of concern associated with inter-basin biota transfer (DLWGGJTC 1997), they were given special attention in this study. As done with other searches, the parasite-related literature search began with the references listed in Schmidt (1999), which were obtained and carefully reviewed. Experts were sought and consulted in an attempt to find any other reports of parasites and pathogens occurring in the DLB, especially any species not reported in the published literature. Fish hatchery and other agency personnel were consulted to determine whether stocked fish were likely to have carried pathogens and parasites from hatchery facilities or other natural waters into Devils Lake, and to determine whether fishes from Devils Lake have already been stocked into other RRB waters.

B. Construct lists of "candidate" PBOC species. Lists of species recorded from the DLB were constructed by compiling occurrence records from all information sources identified in the previous step. Separate lists were constructed for vascular plants, algae, invertebrates (including free-living protozoa), fishes, fish parasites, and fish pathogens, and information sources were recorded for each species. This step revealed errors and omissions in the Schmidt (1999) bibliography, so all original sources were obtained and carefully reviewed for species occurrence records. Discrepancies between original sources and the bibliography were corrected to reflect the original information accurately. Because original papers also could contain errors, the spelling of each scientific name was compared to authoritative taxonomic sources and corrected where necessary. This was necessary because some species' alternative names differ only slightly, and because electronic information searches required accurate spellings.

Because some literature sources were old, taxonomic classification had changed for many species since the source documents were written. Taxonomic databases were used to record taxonomic history and to update species names to their present status, where that status could be clearly determined. When alternative names for the same taxon were encountered in the literature referenced in the bibliography, they were included in the appropriate tables. Synonyms exist for many species names, but most species listed in the tables have no synonyms listed because they were not encountered in the literature reviewed for this study.

The separate effort to find information on vascular plants began with the construction of a list of all species classified by Reed (1988) as OBL (obligatory aquatic species) or FACW (facultative wetland species) and known to occur in North Dakota, according to regional flora lists. This list was compared to published regional flora, unpublished sources provided by local experts, and to the species list developed during the site visit to determine which species were present in the Devils Lake basin and which were in the Red River basin.

C. Add automatically listed species. Several species were automatically added to the Candidate PBOC list. Automatic listings were required for (a) any species listed as an invasive species of concern by government authorities whose jurisdictions include the RRB, and (b) several other species of concern that were specifically named in the Statement of Work. Legally sanctioned lists of invasive aquatic species were sought for North Dakota, Minnesota, Manitoba and Canada as a whole.

D. Create geographically cross-referenced lists of species. Papers on RRB biota referenced in the Schmidt (1999) bibliography, and all additional information collected, were compiled, and each was searched for any records of Candidate PBOC species. All occurrences of these species at specific sites in the Red River basin were recorded, and references were cited for future evaluation of species for PBOC status.

2.1.2 Step 2: Evaluation of Candidate Species

To determine which taxa should be included on the PBOC list, the pool of Candidate species was divided into " PBOC" and "non-PBOC" based on geographic location records for each taxon, and on information about their most apparent dispersal mechanisms.

According to the Statement of Work, a distinction was to be made between species common in the RRB and those with only limited distribution within the basin. However, the temporal and spatial coverage of existing data collected from the RRB was generally inadequate to allow such a distinction to be made. As a result, only a presence/absence criterion was applied: all candidate species recorded from RRB sites were classified as "non-PBOC". This was considered reasonable because almost all RRB data were collected from Lake Winnipeg, the Red River mainstem, or the Sheyenne River, rather than from minor tributaries or isolated waters in remote locales that would suggest highly localized distributions.

2.1.3 Step 3: Finalized PBOC list

Automatically listed taxa were added to those selected as PBOC in Step 2 and certain taxa with obvious existing inter-basin pathways were removed (e.g. Insecta). The remaining taxa comprised the final PBOC list.

2.2 Selection of Biota for Risk Assessment (BRA)

Once the PBOC list was compiled, it was necessary to determine which of these biota should be carried on for risk analysis consideration. To this end, information on the biological characteristics of each taxon was compiled and analyzed in light of existing and predicted habitats and inter-basin transfer pathways. These analyses, described below, provided the grounds for deselecting taxa from the list of taxa for further analysis.

2.2.1 Biological Characteristics of PBOC

To help determine the likelihood that any given species poses an inter-basin biota transfer risk, searches of published literature and up-to-date internet sources on each PBOC taxon were performed. In some cases, multiple species had to be treated as a group, either because the biological characteristics of interest were very similar among lower-level taxa or because too little is known of individual species' life histories to support species-specific accounts. Each account included:

A. life history and life stages, geographical distribution, habitat requirements, and other relevant biological information;

B. body sizes at different life stages, detection methods, and possible detection problems;

C. mechanisms for movement and dispersal;

D. species' functions in ecosystem and potential effects of species' introduction to non-native systems.

2.2.2 Potential for Interbasin Transfer of PBOC

Various factors influenced the assessments of PBOC species' likelihood to be transferred by the proposed outlet. These included information on existing habitats and transfer mechanisms, and projections regarding ways that changes to these factors could enhance interbasin transfer of PBOC. This task included assessments of the following items:

A. Existing Devils Lake habitats and PBOC species enhanced by recent changes. Site visits by project team personnel were used to observe the habitats present in Devils Lake, particularly those new shoreline habitats created by the recent rise in water level. A land-use map prepared by the U.S. Environmental Protection Agency was consulted to infer new habitat characteristics (Figure 2), and inferences were made regarding which PBOC species would likely benefit from the new habitats.

B. Existing interbasin transfer pathways. Literature sources were consulted to determine dispersal mechanisms of PBOC species. Existing pathways from the DLB to the RRB were determined, likely current usage of them was estimated, and the likelihood of the proposed outlet project to alter or add to these pathways was assessed. For cases in which PBOC have not been detected in the RRB despite the probable occurrence of dispersal pathways, available information was used to evaluate possible reasons why the species had not been reported in the RRB.

C. Existing downstream habitats and projected changes due to project. Based on project team site visits, literature, and expert consultations, existing habitats downstream from the proposed outlet were described. Predicted effects of the outlet project, taken from the USACE Devils Lake Outlet Project Background Information documents, were used to estimate expected changes to these habitats. These predictions were gathered from the background information provided on the USACE and USGS Devils Lake project web pages, and from specific published studies, cited in text below. Discussion of habitat changes focused on three categories of physical and chemical changes: (1) erosion, sedimentation and stream morphology alteration, (2) changes in volume and duration of flow, and (3) water chemistry changes.

D. Predicted effects of project on PBOC. Based on the foregoing analyses, predictions were made regarding: (1) the likely impact of the project on PBOC species' relative abundances in communities they might invade or in which they already occur, (2) changes in individual species' ranges, and (3) changes in their potential invasiveness.

2.2.3 Potential for Regulating or Otherwise Controlling Suitability of Pathways

Under this task, pathways were analyzed to determine whether they are subject to government regulatory control, in North Dakota or elsewhere, and/or subject to physical control by the project sponsors through modification of the project (e.g. mitigation measures).

2.2.4 Finalized BRA list

All collected information on PBOC species was analyzed and used as a basis for selection of species to be included on the list of Biota for Risk Assessment. The selection procedure was standardized by using the decision tree described in section 2.0 to classify all species as BRA, non-BRA, and provisional BRA. Provisional BRA were those species that had potential to cause downstream effects only if certain habitat changes also occurred.

2.3 Risk Assessment of BRA Species

According to the Statement of Work, risk analysis procedures were to follow those described in CENR (1999). As described below, no true BRA species were identified, so these prescribed risk analysis procedures were not explicitly followed. However, many of the prescribed risk assessment tasks were completed at earlier steps in the analyses, so at least partial risk assessments were conducted for all PBOC species in the BRA-classification stage of the study. Certain species were found to be of sufficient concern to warrant more attention than required by the Statement of Work for non-BRA species, so these analyses were carried out with the intended purposes of the CENR (1999) and USEPA (1998) procedures kept in mind. This involved describing the potential risks posed by the species, and addressing concerns noted in the Statement of Work, such as the species invasiveness, its likely effects on downstream communities, the likelihood of the species spreading further downstream, and the likelihood of economic costs associated with the species.

3. FINDINGS

3.1 STEP 1: CREATION OF CANDIDATE PBOC LIST

3.1.1 Information Sources Found: Literature and Experts

The first step in creating a candidate PBOC list was to record all known DLB taxa, followed by a similar list of RRB taxa for comparison. The annotated bibliography provided by the USACE (Schmidt 1999) provided the starting point for this task in the form of lists of species reported in the scientific literature. A preliminary review of these original literature sources revealed errors in the bibliography, so a thorough examination of all original sources cited there was necessary. In several cases, older studies that were cited in the primary sources were also reviewed. These activities resulted in several additions and corrections to the species lists. Further, because many studies occurred decades in the past, taxonomy was out of date for many taxa. Considerable effort was expended in verifying and updating taxonomy using various internet resources and searches, but the extensive investigation necessary to establish taxonomic pedigrees for each species exceeded the scope of this study. Nonetheless, many synonyms and revisions were discovered, so the species lists in this report should be considerably more reliable than the raw lists included in the bibliography.

Throughout the assessment, data and input were sought from regioanal biota experts. These consultations provided little additional information on biota of the Devils Lake and Red River basins, and most experts agreed that these systems have not been studied adequately. Appendix 1 contains a list of the experts consulted, their expertise, and affiliation. Summaries of e-mail, telephone, and face-to-face consultations with these experts are also provided in Appendix 1.

Literature searches for sources missed by, or published since, the assembly of the bibliography revealed no additional published studies specific to DLB or RRB biota. However, results from recent studies on the algae of Devils Lake (M. Fawley, K. Phillips, unpubl. data) and the Sheyenne and Red Rivers (M. Fawley, R. Goldstein, K. Phillips, unpublished data) were obtained and used to supplement the Candidate PBOC and RRB lists. Invertebrate data were scarce, and an ongoing study of Sheyenne River and Devils Lake macroinvertebrates had not yet produced useful results (A. DeLorme, pers. comm.).

3.1.2 Summary of Information Found

Literature sources were found that provided lists of fishes, fish parasites, algae, and some invertebrates of Devils Lake, though most of these lists were almost certainly incomplete. No studies were sufficiently broad in temporal and spatial scope to provide reliably complete species lists. Further, none of the studies reviewed included any other waters of the DLB except Stump Lake, which was studied by Young (1924) for several years, and with substantially less thoroughness by Neel (1974), and Peterka (1986).

The most complete record of Devils Lake biota was a very old account of the lake during a period of falling water level and increasing salinity (Young 1924). By the time of that study, the lake had shrunk to such an extent that only the deepest (lowest elevation) portions of the basin retained surface water, creating a complex of spatially distinct lakes and ponds with different chemical and biotic characteristics. Presumably due to elevated salinity levels, the aquatic fauna and flora of the lake complex was depauperate, with only one species of aquatic plant, wigeongrass (*Ruppia maritima*), and few macroinvertebrates present. The algal and zooplankton communities were somewhat richer, with an especially large number of Cyanobacteria and Rotifera species. However, species richness of these groups was still considered low in comparison to fresher waters. A list of protozoan species and a few nematode worms and other meiofauna were reported as well, but no such thorough record of these more obscure organisms has since been produced by workers on either Devils Lake or the RRB. By contrast, records of fish species occurrences have been more thorough, but the only fish species in Devils Lake in Young's (1924) time was the brook stickleback, *Culaea inconstans*, which has persisted to the present.

The modern Devils Lake chain is much larger, fresher, and species-rich as a result of a rising-water level trend since the 1940's, culminating in the sharp rise seen since 1993. Fish species richness is much higher now than in 1924, but even for current conditions, reliable data were not easily obtained. A recent unpublished report (DLWGGJTC 1997) provided a list of fish species present in Devils Lake, but no sources for the information used in that report were cited. The draft report listed fish species that Owen et al. (1981) had not earlier reported as Devils Lake residents, including white sucker (*Catastomus commersoni*), black bullhead (*Ictalurus* -now "*Ameiurus*"- *melas*), black crappie (*Pomoxis nigromaculatus*), white bass (*Morone chrysops*), striped bass (*Morone saxatilis*), and muskellunge (*Esox masquinongy*), although the last three are known to have been stocked in the lake subsequent to Owen's assessment. In contrast, fish species of the Red River system have been well-documented by Owen et al. (1981) and Peterka and Koel (1996).

Recent studies of algae (Leland and Berkas 1998, Peterka 1986, Phillips unpubl. data, and Sando and Sether 1993), and zooplankton (Peterka 1986) provided the most up-to-date records of Devils Lake biota. However, zooplankton work has been limited, and studies of other invertebrates and vascular plants have not been conducted for several decades. Most records of Red River basin biota were in the form of recent unpublished studies of algae of the Sheyenne River (M. Fawley, and K. Phillips, pers. comm.), older work on Lake Ashtabula's benthic invertebrates (Peterka 1972) and planktonic algae (Peterka and Reid 1968), and the studies of algae and macroinvertebrates of the Red River (R. Goldstein, unpubl. data.). Several studies of Lake Winnipeg's zooplankton (Cobb 1996, Patalas 1981, Patalas and Salki 1992, Salki 1996) provided a thorough record that was not matched for any other biota group.

Several sources of information on vascular plant species were found among local experts and institutions. None explicitly defined the flora of the DLB or of Devils Lake proper, but the sources were sufficient to allow many inferences to be made. A list of 218 plants of Camp Grafton (located on the Devils Lake shore) was obtained at the North Dakota State Herbarium (W. Barker, S. DeKeyser, unpubl. data). Site visits by team members resulted in lists of 179 species from the Red River basin and 60 species from Devils Lake. County-specific records (Barker and Mitchell 1977) were also reviewed, and species were added to the overall lists as necessary. Cross-referencing these lists provided a final Candidate PBOC list with geographic references.

Consultations and literature searches provided no positive identification, or even anecdotal evidence, of DLB fish pathogens. Some fish species, such as walleye (*Stizostedion vitreum*), northern pike (*E. lucius*), and (*E. masquinongy*) muskellunge, originate from Garrison Dam

National Fish Hatchery and Valley City National Fish Hatchery, both of which are certified disease free (J. Weigel, pers. comm.). On the other hand, some fish species, such as yellow perch (*Perca flavescens*), black crappie, and white bass, have been captured wild from other lakes. At one time or another, every major lake in the state has served as both source and destination of wild-caught fish for stocking (J. Weigel, pers. comm.), so natural barriers to fish pathogen transmission have been repeatedly circumvented by human actions.

Some information on fish parasites was available, but only one study (Reinisch 1981) included Devils Lake, and no local expert was found who could provide more detailed information or verify the published account. No disease or parasite problems have been reported from the lake (R. Hiltner, pers. comm.), but routine monitoring protocols are not in place in North Dakota, so the lakes' fishes may harbor undetected parasites and/or pathogens (J. Weigel, pers. comm.). Red River tributary fish parasites were identified by Sutherland and Holloway (1979) and Forstie and Holloway (1984), with some additional information provided by local experts (T. Dick, J. Marcino, and J. Weigel, pers. comm.).

State officials did not have information on bait fishes, but according to a local bait vendor (K. Bakken, pers. comm.), the only bait fish found to be sold in the area year-round were locally trapped fathead minnows. In the spring, a local wholesaler supplies shiners and lake chubs that may originate from another state, but sources appear to vary from year to year.

Species automatically listed as PBOC were included in the Statement of Work, and are listed in Table 1. They included all aquatic Minnesota Prohibited Exotic Species (Minn. Rules 6216.0250) and Minnesota Regulated Exotic Species (Minn. Rules 6216.0260). No similar categories were found in North Dakota’s Century Code or administrative rules, or in Manitoba statutes or regulations. None of these government-listed species have been recorded from the Devils Lake basin, but they were included in the PBOC list because of their known potential for invasiveness and detrimental effects on native species. Of the 42 automatically listed PBOC, only the striped bass (*Morone chrysops*), and possibly some of its parasites, has ever been known to occur in Devils Lake. However, all of the noted species were included as PBOC nonetheless, as dictated by the Statement of Work.

3.1.3 Candidate PBOC List Assembly

Review of all data sources noted above provided the names of biota known to occur in the DLB. These included 527 algae (Table 2), 353 plant (Table 3), 94 protozoa (Table 4), 146 invertebrate (Table 5), 12 fish (Table 6), and 8 fish parasite (Table 7) taxa, plus one pathogen of birds. Collectively, these names formed the Candidate PBOC list. This was believed to be the most complete list of DLB biota that could be assembled based on authoritative information sources (anecdotal and other unverified information was not sought).

Amendments to this list will be necessary in future. Ongoing surveys (e.g. macroinvertebrate studies by A. DeLorme, fish pathogen screening by USACE) and future studies of Devils Lake biota are necessary to improve knowledge of certain components of the flora and fauna about which very little is known (e.g. known exotic invasive species, macrophytes, meiofauna, deep-water benthic invertebrates, benthic and periphytic algae). Also, many taxa inclusions on the list were based on information from times when habitat conditions in the lake were much different, so some listed species may no longer occur in Devils Lake.

3.2 Step 2: Selection/Deselection of Candidate Species for PBOC Status

To produce the PBOC list, deselections were made from the Candidate list based mainly on distribution criteria. All taxa that occurred in both the DLB and RRB were "cut" from the list at this point. The Statement of Work called for the breadth of distribution of each taxon within the RRB to be considered so that only those taxa broadly distributed in the RRB would be deselected. However, after initial attempts to consider breadth of distribution, it was decided that existing information was inadequate to allow such determinations to be made, so a presence-absence criterion was used.

Deselecting taxa that were known to occur in the RRB (the first "cut") produced the following result. Of 1182 Candidate taxa, 312 algae taxa (Table 2), all 353 plant taxa (Table 3), zero protozoa taxa (Table 4), 38 invertebrate taxa (Table 5), 11 fish species (Table 6), and 5 fish parasite species (Table 7) were found to occur in both basins. The single bird pathogen was retained, despite its known occurrence in RRB waters, because it is a pathogen of economically important animals. Further analysis was needed to determine whether Devils Lake was a particularly favorable habitat for the pathogen. These were all deselected, leaving 215 algae, 108 invertebrate, 94 protozoa, 1 fish, 0 plant, 3 fish parasite taxa and 1 bird pathogen for further evaluation (zero fish pathogens, zero fungi).

The second "cut" involved a decision to deselect two groups because of their obvious and very effective existing interbasin transfer mechanisms: insects and water mites ("Hydracarina" in Table 5). Insects readily disperse among basins by flight, and all Candidate mites spend a portion of their life cycle as ectoparasites on flying insects, so they are carried to all waters visited by these insects. The removal of the 35 remaining insects and mites reduced the invertebrate list to 73 taxa.

Finally, the 42 automatically listed taxa were added to the 386 selected as PBOC, so the final PBOC list consisted of 429 taxa (Table 8).

3.3 Finalized PBOC Selections - Summary by biota group

3.3.1 Vascular Plants

Published literature sources of plant data from Devils Lake were old, and included only five plant species (presumably because diversity was low in more saline conditions). Inferences made from flora lists and site visits resulted in a long list of Candidate PBOC species, but all were deselected from the PBOC list because they were found to occur somewhere in the Red River basin. Thus, the only PBOC vascular plant species were the 14 species listed in Minnesota statute as Prohibited or Regulated.

3.3.2 Algae

PBOC algae were drawn from sources listed in the USACE bibliography (Schmidt 1999), including those listed in the main table of algal species, and those listed in the Appendices. Additional species from Anderson and Armstrong (1966), Armstrong et al. (1966), Conway (1983), Shubert (1976), Verch and Blinn (1972), and Young (1924) were also included. A large number (215) of algal species were included as PBOC because they have been recorded from Devils Lake, but not from the RRB. A total of 312 species occurring in Devils Lake were excluded from PBOC listing because they have also been recorded from the Red River, the Sheyenne River, and/or Lake Winnipeg, and surrounding areas within the same basin. However, studies from both systems are most likely incomplete, and comparability of studies conducted between the two basins is relatively low. Many species likely to exist in both basins have not been detected in either area. Further, studies within the RRB have not been sufficiently extensive to allow confident assessment of how widespread, or localized, many algae species are within the basin.

3.3.3 Fishes

All but one of the 18 fish species included as PBOC were automatic listings. None of these species, except striped bass (*Morone saxatilis*) has been recorded from the Devils Lake basin. Striped bass were stocked in Devils Lake in 1977 but all evidence suggests that they have not established a reproductive population or hybridized with white bass (*Morone chrysops*) (DLWGGJTC 1997). Muskellunge (*Esox masquinongy*) was not an automatic listing, but it has been established in Devils Lake since its 1976 introduction. It was deselected from the PBOC list because it has been introduced into the Red River and Sheyenne River several times. It is not clear whether the introductions have succeeded in establishing reproductive populations, but individuals are periodically caught in the basin. The tiger muskellunge (*Esox lucius X masquinongy*) has been stocked in Devils Lake, but it is a sterile hybrid, so it is incapable of sustaining a population in any waters unless repeatedly stocked. All other species known to occur in Devils Lake are also common in the Red River and its tributaries (Peterka and Koel 1996), so they were excluded from the PBOC list.

3.3.4 Invertebrates

Macroinvertebrate studies of the DLB and RRB have been rare, and taxonomic resolution of the resulting data is inconsistent, so few species are recorded from these basins. Candidate PBOC taxa (family, genus, and species) were gathered from the USACE bibliography sources (Schmidt 1999) and Young (1924). All Candidate insect and water mite (Hydracarina) taxa were deselected from the PBOC list because the insects have flight capability and the mites spend a portion of their life cycle as ectoparasites on flying insects. Therefore, all these taxa have existing overland transfer pathways that would overwhelm any transfer created by the outlet.

Of the remaining invertebrates, records of microinvertebrates (zooplankton, meiofauna) of the DLB were gathered from the sources cited in Schmidt (1999) and, especially, Young (1924). These were compared to records from the Red River basin from sources cited in Schmidt (1999) and from studies by R. Goldstein (unpubl. data). Numerous studies of DLB and RRB zooplankton crustaceans were found, but all other invertebrates have been nearly ignored in past research. Young (1924) published the most complete record of Devils Lake invertebrates by far, resulting in a long Candidate PBOC list. But the lack of similar studies in RRB waters resulted in most of these taxa being included as PBOC by default, rather than because of any confidence that they do not occur in the RRB. Protozoa, Rotifera, and Nematoda, in particular, were studied intensively in Devils Lake by Young (1924), but have been virtually ignored in the RRB. These three taxa combined added 147 taxa to the PBOC list.

3.3.5 Pathogens & Parasites of Fishes

No records of pathogens or diseases of fishes in the DLB were found, so no pathogenic species were included as PBOC other than those automatically listed. Fish parasite records were gathered from the sources listed in Schmidt (1999), and 3 species were included as PBOC. The remaining species recorded from Devils Lake have also been found in the Red River system, so they were excluded from the PBOC list. It is likely that the records from both basins are incomplete because so few published studies exist.

3.3.6. Pathogens & Parasites of Mammals, Birds, Reptiles and Amphibians

Avian botulism has occurred in waters of the Devils Lake basin. The pathogen is widespread, being carried by waterfowl, but it requires certain environmental conditions to become infectious in large outbreaks. The particular conditions in Devils Lake waters have apparently been favorable for the disease, so it was retained as a PBOC for further analysis.

3.4 DESCRIPTION OF DATA DEFICIENCIES

The Statement of Work dictated casting a "wide net" to include a large number of species on the PBOC list, so a large number of taxa were retained as PBOC, despite the fact that most would probably be deselected if complete records of the the biota of both basins were available. For example, the 94 protozoa from Devils Lake were included only because there were no records of protozoa from the RRB available. A survey of RRB protozoa would probably find all DLB species within the RRB.

This example indicates the most important hindrance to the accurate assessment of potential Devils Lake outlet impacts using existing data. Large gaps in presence/absence and geographic distribution data for most species precluded a complete account of the biota that could pose problems in the event of biota transfer through a Devils Lake outlet. This is a substantial, but presently unavoidable, shortcoming in the reliability of the overall risk assessment presented herein. The breadth and depth of data deficiencies are described below.

3.4.1 Lack of Data Comparability

Accurate comparisons of the biota of the DLB and RRB were precluded by the lack of similarity between the types of studies conducted in each basin. The studies were not comparable for many reasons, including:

1. Studies were conducted in dissimilar habitats (e.g. lotic, freshwater Red River basin sites vs. lentic, brackish Devils Lake sites).
2. Sampling intensity varied among studies, for example, a recent algae study included sampling sites along several Sheyenne River reaches, but only one site on the western shore of Devils Lake (M. Fawley, pers. comm.).

3. Taxonomic focus varied among studies, for example Young (1924) provided lengthy lists of protozoan and rotifer species from Devils Lake, but no studies of these biota have been conducted in the Red River basin.

4. The level of taxonomic resolution varied among studies; so species could not always be compared among studies.

5. When data from the same taxonomic group were found from both basins, they were often from studies that were widely separated in time.

6. Data sources were of various ages, with data collected under various water-level and environmental conditions in the source and potential destination basins.

Recent efforts to conduct similar studies of algae in both basins are a step in the right direction, but even these studies have suffered from being conducted in dissimilar habitats (Devils Lake vs. Sheyenne River) and covering only a small portion of each basin's waters.

3.4.2 Taxonomic Gaps in Data

Even if studies in the RRB and DLB had been comparable, substantial gaps in taxonomic coverage of present-day habitats would prevent a fully reliable assessment of biota transfer risks. These gaps are summarized by biota group below.

A. Vascular plants. No Devils Lake or DLB wetland/aquatic flora lists were found, with the exception of five species mentioned in various sources listed in Schmidt (1999). Accordingly, a comprehensive list of Candidate PBOC plant species could not be created. Reliable regional records were consulted, but it was not possible to determine which species actually occur within the DLB without field investigation. During field visits to Devils Lake, project team members did prepare a partial list of vascular plant species observed in and around Devils Lake. This list does not constitute a systematic survey but was used in developing a candidate PBOC list.

B. Algae. Fairly recent studies of algae, combined with historic studies, provided a long list of algal species found in Devils Lake. However, the list was probably incomplete because the investigations cited suffered from certain shortcomings: (a) sampling was conducted over very limited temporal and spatial scales, (b) sampling was restricted to only a subset of habitats, and (c) sampling was restricted to Devils Lake only, ignoring the other surface waters of the basin. Algae of the Sheyenne and Red Rivers have been studied recently, also generating long species lists, but these studies also were limited in temporal and habitat scope. Despite the above-noted shortcomings, the algae data were substantial and reasonably reliable for the purpose of this study. However, field study comparing similar habitats in both basins would almost certainly reveal more common species records, indicating algal flora that is more similar between the two basins.

C. Fishes. Fish species records from Devils Lake were complete and reliable, except that no recent records from other waters within the DLB were found. Fish species records for the RRB were also fairly complete and reliable. Given the recent habitat changes in Devils Lake, more current data would probably reveal changes in the abundance and distribution of species within the lake. However, such changes would not in and of themselves result in the presence of fish species in the lake that had previously been absent.

D. Non-Parasitic Invertebrates and Protozoa. Few studies of invertebrates of Devils Lake have been conducted. The most complete and reliable survey was very old (Young 1924), yet provides more complete records for some groups (e.g. Protozoa, Rotifera, Nematoda) than exist for the Sheyenne or Red Rivers. The few other data sources were very incomplete, based on samples that were very limited in spatial, temporal, and habitat scope, and including very few identifications to the species level. Many taxa were not identified to even genus or family level. These taxonomic limitations are not uncommon in the invertebrate literature, but the other shortcomings in the data result in a very poor level of understanding of the Devils Lake invertebrate fauna. Sheyenne River fauna have been even less studied, although a macroinvertebrate study is presently ongoing (A. Delorme, pers. comm.). The study being performed by Dr Andre Delorme may not produce species-level results unless a specific commitment is made to obtain this level of detail. A Red River macroinvertebrate data set was found (R. Goldstein, pers. comm.), but it also suffers from lack of taxonomic resolution and incomplete spatial, temporal, and habitat coverage. In sum, the present state of information on free-living invertebrate species is very far from complete for both basins.

E. Parasites of fishes. Recent studies of metazoan parasites of fishes of Devils Lake (Reinisch 1981) and the Sheyenne River (Forstie and Holloway 1984, Sutherland and Holloway 1979) provided reliable parasite species information, though it was dated and incomplete. No data were found for any other Red River basin sites, and thoroughness of the Red River basin records was even more questionable, because some fish species were little studied and geographic coverage was incomplete. Many species found in Devils Lake were common, widespread, non-host-specific, and easily spread by avian definitive hosts. Yet they have not been recorded from Red River basin waters, due most likely to the lack of research rather than the absence of such species.

F. Pathogens of fishes. No records of fish diseases or pathogens in either the DLB or RRB were found though intensive literature search and expert consultation were undertaken. While no pathogen data may have been collected, the lack of anecdotal reports of diseased fish or fish kills suggests that fish pathogens have not caused significant problems to date. A fish pathogen screening study currently being undertaken by the St. Paul District of the USACE is expected to substantially improve understanding of fish pathogens in both basins.

G. Parasites and pathogens of other vertebrates. Records of avian botulism outbreaks on Devils Lake were the only records of other vertebrate diseases found. Other diseases have not been apparent in Devils Lake wildlife (R. Hiltner, pers. comm.).

H. Minnesota Prohibited and Regulated Species. No records of Minnesota-listed exotic invasive species presence in the Devils Lake basin were found, but few surveys of appropriate taxa (e.g. crayfish, macrophytes) have been done recently. The lack of records could therefore represent true absence or lack of detection effort.

3.4.3 Overall Assessment of Data Adequacy

According to the Statement of Work, the review of existing literature on biota of Devils Lake and the Red River basin was intended to: (1) "identify which organisms...referenced in the COE document should be included on the PBOC list", and (2) "determine whether the past biota inventories of Devils Lake and its immediate watershed are adequate and up to date" according to eight specific questions. Each of these questions is quoted below, followed by answers based on this study.

- *Have there been changes in habitats since the inventories were done that could cause substantial changes in species composition and abundance?*

Yes. Devils Lake has undergone water-level fluctuations and an altered hydroperiod since the earliest studies cited in this report. These changes in water level have altered concentrations of dissolved nutrients and other ions, particularly sulfates. Young (1924) described a lake that was becoming increasingly shallow and concentrated, and predicted that it would dry completely. The lake nearly did go dry in the 1940s. Since then, the water level has risen erratically, with relatively low periods in the 1960s and just prior to the dramatic water level rise seen since 1993. Studies of the lake have occurred during various parts of this water level and chemical history, so they represent biological conditions under often very different habitat conditions. Even studies conducted since 1993 may not be considered to represent present conditions because the pace of change has been so rapid, and new community equlibria have almost certainly not been reached.

- *Was the methodology to identify biota deficient compared to methods now available?*

No. Studies cited herein appear to have used procedures that are considered acceptable under current scientific sampling and identification regimes.

- *Were the inventories geographically appropriate, given the current state of knowledge regarding exotic species invasiveness, and spread of pathogens and parasites?*

Because none of the studies appear to have been conducted with exotic species as a focus, this question cannot be answered with certainty. Most studies were conducted before exotic species were commonly under surveillance, and present-day exotic species of concern were not present in the region at the time of most studies.

- *Were geographic areas left out of the inventories?*

Yes. Devils Lake basin studies have focused exclusively on Devils Lake and Stump Lake, with the exception of fish records (Owen et al. 1981). Thus, no information on non-piscene biota of other waters within the Devils Lake basin have been collected. Similarly, the majority of Red River basin waters have not been studied for non-piscene biota. Most studies reviewed in this report included only the Sheyenne River, Lake Ashtabula, the Red River main stem, and Lake Winnipeg. The only exceptions were the inclusion of Matejcek Lake in the Red River basin in North Dakota by Taylor et al. (1979b), fish data from many of North Dakota's Red River tributaries (Owen et al. 1981), and zooplankton records from the Experimental Lakes Area within the Lake Winnipeg basin (Patalas 1971).

- *Is the data concerning the populations of problem species that were identified adequate for the impact assessment?*

No. With the exception of striped bass, surveys for exotic species have not been done in the Devils Lake basin. Recent habitat changes and increased recreational boating in Devils Lake suggest a need for exotic species monitoring within the basin. Red River basin data are somewhat more substantial, including records of Eurasian watermilfoil, flowering rush, purple loosestrife, and rusty crayfish.

- *Have the practices of the bait industry, aquaculture industry, or federal and state resource management agencies changed the populations where the inventories were done?*

Yes, but this is only known in the case of game fish stocking by authorized agencies. Without such stocking, the lake would presumably not have recovered its fish community since its decimation during the last drydown period, when the only fish species present was brook stickleback (Young, 1924). Devils Lake stocking and subsequent fish community changes have been fairly well documented. Changes due to aquaculture, bait introductions, and other unauthorized human-mediated introductions are unknown.

- *Have problematic and invasive biota appeared in the Devils Lake basin since the inventories have been done?*

This is unknown because studies are lacking. However no records or anecdotal information suggesting new introductions of such species were encountered.

- *What is the level of confidence in the past inventories? What is the range of the inventories (comprehensive or species specific)?*

Confidence in methodology and reliability of past studies is not in question (any more than for any reports of professional scientific work), but most of the studies cannot be considered complete or even partial inventories. Confidence in the thoroughness of the inventories compiled for this study is low, because of the cited sources' spatial, temporal, seasonal, habitat, microhabitat, and taxonomic limitations, as well as their lack of inter-site comparability in these factors (as described above).

3.5 FACTORS AFFECTING SELECTION OF BIOTA FOR RISK ASSESSMENT

3.5.1 Biological Characteristics of PBOC

To help determine the likelihood that any PBOC species might pose biota transfer risks, searches of published literature and up-to-date internet sources on each PBOC species were performed. The resulting individual accounts of PBOC species follow. In some cases, several to many species within a given taxonomic group were lumped because their biological characteristics either differ very little, or too little is known of individual species' life histories to support species-specific accounts.

3.5.1.1 Biology of PBOC: Algae

Basic biology for all algal groups is described here, with most information drawn from Bold (1978), Round (1981), Sandgren (1988), Smith (1950), and Stevenson et al. (1996). More detailed discussions of certain groups and species are included farther below.

Kingdom Eubacteria;
- **SubKingdom Cyanobacteria or Phylum Cyanophyta - "blue-green algae"**

Kingdom Protista;
- **Phylum Chlorophyta - "green algae"**
- **Phylum Chrysophyta**
  - **Sub-Phylum Bacillariophyceae - "diatoms"**

Sub-Phylum Chrysophyceae - "yellow-brown algae"
Sub-Phylum Xanthophyceae - "yellow-green algae"
Phylum Cryptophyta
Phylum Euglenophyta
Phylum Pyrrhophyta - "dinoflagellates"

Life History and Distribution

All algae, except Cyanobacteria, are protists. In fact, within the Kingdom Protista, there is no sharp division between the protozoa and the algae, so the term "algae" denotes those protists that are primarily photosynthesizers. Therefore, the life history and general biological characteristics of protozoa and algae are very similar.

Representatives of all major algae groups are found in most habitats throughout aquatic habitats worldwide. They differ more in biochemistry, particularly their mix of photosynthetic pigments, than in any other characteristic, with a few exceptions. Some anatomical differences are commonly used to distinguish among algal groups, the most obvious of which is the unique two-piece, silicious "shell" enclosing all diatoms. The Cyanobacteria differ from all other algae in ultrastructure because they are prokaryotes classified in the same kingdom as "true" bacteria. They also differ in that some species can secrete a mucilage sheath for protection and colony adhesion, and in the fact that many species can use, or "fix", gaseous nitrogen from the atmosphere, rather than depending on dissolved nitrogen compounds.

Representatives of all these groups can be found among the plankton, the benthic, and the periphytic algal flora of inland lakes, though planktonic algae have probably been best studied. Most species have wide geographic ranges and show some variability in habitat needs. Habitat preferences and geographic distributions for each PBOC algae species are listed in Table 9. The benthic algae are generally named according to the substrate on which they are found: epipsammic algae on sandy bottoms, epilithic algae are attached to rock surfaces, epipelic algae often form mats on submerged soil surfaces. The various groups also have representatives that are filamentous, colonial, and unicellular, but the individual organism is unicellular, so binary fission is the typical reproductive mode. Sexual exchange of genetic material is frequent among algae, but not necessary for reproduction. They are capable of very rapid population growth when conditions for the species are optimal, hence the tendency of many species to form blooms.

Size and Potential Detection

Filamentous algae are the easiest to detect because they often form macroscopic filaments, and interwoven mats of these filaments are not uncommon. In general, however, algae are often overlooked by the novice, and must be sought by experts. Detection is not difficult if standard methods are followed, but a full accounting of the algal flora of any water body must include sampling from plant stems, benthic muds, rock and wood surfaces, and other microhabitats, as well as plankton sampling. For this reason, complete flora for a single water body are often not collected.

Movement and Dispersal Mechanisms

Many algae move on their own using mechanisms typical of protists, such as flagella (e.g. euglenoids) and secretions that propel them in a gliding motion (e.g. diatoms), but dispersal within water bodies depends on passive transport via water movements. Overland dispersal is not fully understood, but transport via wind and, especially, animals, has been demonstrated.

Ecological Roles

By definition, the algae are photosynthetic autotrophs, so they are the main primary producers in many aquatic ecosystems. As such, they form the base of aquatic food webs, although filamentous algae and especially the Cyanobacteria are often very poor conduits of energy and biomass to higher trophic levels because they are unpalatable or difficult for many organisms to eat. Diatoms play a unique role in aquatic systems as the primary biotic storage compartment of silica, from which they create their shells.

3.5.1.2 Biology of PBOC: Vascular plants - MN Prohibited and Regulated Species

The State of Minnesota formally lists the following 14 species of vascular plants as exotic and or prohibited under Chapter 6216 MRC, Section 6216.0250 and 6216.0260. Numbers 1 and 2 are regulated in commerce and may be bought and sold for hobby aquarium applications. The remaining species may not be traded in commerce, Imported or planted within the state.

Common Name	**Scientific Taxon**
1. Carolina fanwort	***Cabomba caroliniana* A. Gray**
2. parrot's feather	***Myriophyllum aquaticum* Verdcourt**
3. African oxygen weed	***Lagarosiphon major* Moss ex Wagner**
4. aquarium watermoss	***Salvinia molesta* Mitchell**
5. Australian stonecrop	***Crassula helmsii* Kirk Cockayne**
6. curly-leaf pondweed	***Potamogeton crispus* L.**
7. Eurasian watermilfoil	***Myriophyllum spicatum* L.**
8. European frog-bit	***Hydrocharis morsus-ranae* L.**
9. flowering rush	***Butomus umbellatus* L.**
10. hydrilla	***Hydrilla verticillata* (L) Royle**
11. Indian swampweed	***Hygrophila polysperma* Anders**
12. purple loosestrife	***Lythrum salicaria* L.**
13. water aloe	***Stratiotes aloides* L.**
14. water chestnut	***Trapa natans* L**

The foregoing listed species could or have become invasive and dominant to the point of exclusion of native flora and/or fauna, if released within a suitable aquatic habitat. Several, including numbers 1, 2, 3, 4, 5, 8, and 11 are restricted, under the most favorable growing conditions to the regions of tropical and humid subtropical climate of southern United States or temperate maritime climates United States. These are primarily species maintained in public or private aquariums, which could not propagate and/or have no record of survival near the latitudes nor within the continental cold climate of Red River Basin project area. Number 14, water chestnut, could possibly survive in the region, however thee are no records of populations of the species in Minnesota or North Dakota. The species appears to be limited in distribution to the New England area and is not reviewed further, since it has not migrated 200 miles since its establishment in Asa Gray's greenhouse.

Alternatively, number 10 (*Hydrilla*), is also presently limited distributed to the east and west coastal areas, as from tropical climates to as far north as Puget Sound (USGS drainage maps

2000www.Nas.er.usgs.gov/plants/docs/ hy_verti/.html). While not likely a risk for transfer from Devils Lake, it is reviewed because it seems to be expanding its range into continually cooler climates and could make an appearance by the time of discharge from the lake.

Number 13, *Stratiotes aloides*, is probably a relic of incorporation of the Federal Noxious Weed List by Minnesota when it passed its controlled plants species legislation. It was noted for removal from the Federal Noxious Weed List, as published in 60 FR 15260, March 3 1995, thus deserves no further attention.

The growth and reproductive biology of the remaining species, while either not known to occur in the Devils Lake Basin or already documented to occur in both the Devils Lake Basin and the Red River Basin, is further characterized, herein.

Minnesota also lists "nonnative water lilies (*Nymphaea* spp. L.), or any variety, hybrid, or cultivar thereof", as prohibited species. There are several hundred non-native water lily forms occurring or commercially available, worldwide. Since many attractive forms are favored or used in ornamental aquaculture, there is active, market-driven greenhouse hybridization of many forms. There are societies dedicated to the manipulation and propagation of the genus *Nymphea*. An attempt to characterize the genus would thus be overwhelming, possibly futile and certainly peripheral to the issue of interbasin species transfer from the North Dakota Devils Lake Basin.

6. *Potamogeton crispus* curly-leaf pondweed

Life History and Distribution

Curly-leaf pondweed is a non-rhizomatous rooted aquatic herb that, in contrast to most other members of the Potamogetonceae (pondweed family), is distinctive in appearance and fairly easy to recognize by the layman. Its typically submerged spear-shaped leaved are wavy-undulate along the margin and deep emerald green. The dense spiral clusters are not unappealing and provide diverse habitat for many aquatic animals. Flattened, leaf-bearing stems up to about 3 feet in length, support many two-ranked leaves up to 3 inches long. Leaves attach stalkless to the stem. Turions are prolifically developed on stems above leaf connections and at the tip of the plant. Flowers form underwater and develop into sessile, broadly rounded, firm to slightly concave fruits that are fully developed by mid summer.

The habitat most suitable for *P. crispus* proliferation is quiet ponds, lakes waters and stream backwaters, rather than flowing stream verges. Adjacency, at least seasonally, to flowing waters benefits its spread through vegetative reproduction. It is particularly successful in brackish, alkaline or eutrophic waters (Stuckey, 1979). It can tolerate climate variation from tropical to continental cold winter due to its dormant vegetative reproductive structures.

Curly-leaf pondweed develops flowers and fruit in late spring to early summer. During the same period, vegetative reproductive forms, turions, sprout along stems. Turions are succulent, scaly bud-like structures (dormant growth apices), which much like tubers serve to disseminate the plant. They are easily detached, if not deciduous, and fully capable of growing into a clone of the parent plant. Leaves and stems wither and sink to the bottom shortly after flower-set, but fruits and turions remain. While seed germination is virtually unobserved, turions germinate *en masse* in late summer and early fall. The durable turion clones maintain low energy growth lying on the lake bottom through the fall and winter (even under ice), rise and grow rapidly into reproductive plants the next spring. Many standard aquatic weed control approaches have failed to control this species due to this unusual life cycle.

P. crispus is native to the vast Eurasian steppe. It has spread throughout the world, chiefly by the fishing and aquarium industries. It has been recognized as an invasive, noxious weed in at such far-flung locations as Australia, New Zealand, South Africa, Chile, Costa Rica and Canada. The Canadian Wildlife Service (2001) classifies it as a "minor" weed, noting its distribution only along the southern provinces, east of Lake Superior. The Natural Resource Conservation Service (NRCS, 1997) maps *P. crispus* in every State, except Maine, Delaware and South Carolina.

Curly-leaf pondweed was introduced into North America sometime in the late 19th century. One report (MN Cons. Vol. 2001) suggests it was brought along in containers used to transport common carp from Germany to the United States. By 1950 it had spread to most states and several Canadian provinces (Catling et al, 1985). Since then, it has been further introduced by boats, trailers and possibly the aquarium industry to hundreds of thousands of lakes and streams.

P. crispus was mapped by AFGP in 1979 as not occurring in the Red River Basin. The closest populations were eastern Montana, southern South Dakota and southeastern Minnesota. USGS 1999 records the species as occurring in Barnes County, North Dakota, apparently in the highly eutrophic waters of Lake Ashtabula (Phillips, 9/01, personal communication). Considering the present wetter than normal period and higher frequency of flooding in the Sheyenne River, it seems likely that the turions have been carried past the dam and into the Red River main stem.

<u>Ecological Roles and Economic Importance</u>

P. crispus forms surface mats in early summer that interfere with and often prevent aquatic recreation. Decaying vegetation, later in the summer and early fall degrades water quality, and is both malodorous and unsightly. Beaches may be covered with mounds of decaying leaves with adequate wind fetch. Control or removal, once this species has been established, is always costly and often ineffective.

<u>Control Methods</u>

Curly leaf pondweed is highly susceptible to the contact herbicides Diquat, Endothall and AquaKleen, due to the large exposure of leaf surface of the vigorous plant (OSU 2001). Many chemical treatments, applied during the warmer water periods to maximize chemical effectiveness, and also when leaves are most luxuriant, are typically unsuccessful in controlling the species. Both fruits and turions have fully formed by this time in the growing season, against which the chemicals have little effect. Already decadent leaves are killed but turions sink below the reach of the concentrated chemical and seed structure resist penetration. Netherland et al, 2000 reports that improved control can be achieved by increasing turion mortality with treatments in early spring (when rising turions begin to germinate) or in late fall (low water levels). Reduced chemical effectiveness due to cooler temperatures is offset by increased ability to bring the chemicals into contact with sensitive plant parts.

Mechanical removal of *P. crispus* mats has been effective in southern Minnesota (Catling and Dobson, 1985) for improving seasonal recreational use of infested lakes, however mechanical disturbance may actually assist in turion distribution, assuring that the infestation will return the next growing season. Turion formation is strongly affected by temperature and effective day length (Sastroutomo 1980), (Songdi et al, 1989), (Songdi et al 1990). Higher temperatures and longer day length initiate and regulate turion growth. Lowering water temperatures and decreasing available light to the lower parts of the plants will reduce turion development and increase early mortality (Chambers et al, 1985). Creating artificial turbidity through dying of lake waters has been used with some success. To be effective dye must remain in waters for several weeks. Covering with sheets of black plastic has also been attempted in small areas (Helfrich et al, 2000). Lake size, effects to other flora and fauna and aesthetic concerns limit the use of these techniques.

Pine and Anderson 1990 report success in controlling *P. crispus*, among other aquatic plants through the introduction of yearling triploid (sterile) grass carp (*Ctenopharymgodon idella*). Virginia Fish and Game (Helfrich et al, 2000) recommends introducing about 12, 9-12 inch fish per acre. A draw back with this method is the waste produced by the increased numbers of fish herbivores may actually stimulate weed growth.

7. *Myriophyllum spicatum* Eurasian Watermilfoil

Life History and Distribution

Eurasian watermilfoil (EWM) may have been introduced to the North American continent at Chesapeake Bay in the 1880s, although Couch and Nelson present evidence that the first collection of EWM was made from a pond in the District of Columbia during the fall of 1942. By 1985, EWM had been found in 33 states, the District of Columbia, and the Canadian provinces of British Columbia, Ontario, and Quebec.

Like many milfoils, EWM is a submersed perennial plant with finely dissected feather-like leaves. The leaves are arranged in whorls of 4 (rarely 5) around the stem at each node. While usually submersed, in situations where water evaporates slowly and the plants gradually become stranded, EWM can develop into a land form. The leaves of the land form are smaller, stiffer, and have fewer divisions. If such plants are submerged, new growth with aquatic leaves develops in 7-10 days, but the first leaves formed have relatively few divisions and only later does the number of divisions increase to more than 12 leaflet pairs.

EWM is an extremely adaptable plant, able to tolerate and even thrive in a variety of environmental conditions. It grows in still to flowing waters, can tolerate salinity's of up to 15 parts per thousand (half the salinity of Puget Sound in Washington), grows rooted in water depths from 1 to 10 meters (regularly reaching the surface while growing in water 3 to 5 meters deep), and can survive under ice. It is able to tolerate pH levels from 5.4-11. Relative to other submersed plants, EWM requires high light, has a high photosynthetic rate, and can grow over a broad temperature range. EWM grows best on fine-textured, inorganic sediments and relatively poorly on highly organic sediments. Over the spectrum of infertile to enriched aquatic systems, EWM appears to prefer an approximate mid-point, although it occurs in ultra-oligotrophic lakes like Lake Tahoe in California and Lake Chelan in Washington and in hyper-eutrophic lakes.

EWM exhibits an annual pattern of growth. In the spring, shoots begin to grow rapidly as water temperatures approach 15 degrees centigrade. When they near the surface, shoots branch profusely, forming a dense canopy. The leaves below 1 meter senesce in response to self-shading. Typically, plants flower upon reaching the surface (usually in mid to late July). After flowering, plant biomass declines as the result of the fragmentation of stems. Where flowering occurs early, plant biomass may increase again later in the growing season and a second flowering may occur. During fall, plants die back to the root crowns, which sprout again in the spring. In areas with mild winters, like western Washington and Oregon, EWM frequently over-winters in an evergreen form and may maintain considerable winter biomass. EWM plants do not form specialized over-wintering structures such as turions. Carbohydrate storage occurs throughout over-wintering shoots and roots.

EWM is native to Europe, Asia, northern Africa and also occurs in Greenland. EWM is mainly a problem plant in North America, but it has been reported from Australia. In North America, EWM is found from Florida to Quebec in the east, and California to British Columbia in the west. It appears to be primarily spread from waterbody to waterbody through boating activity, although anglers have been known to deliberately plant this species in lakes. A number of populations found in Oklahoma were introduced by earthworm farmers who packed their product in EWM.

The species *M. spicatum* L. var. *exalbescens* is mapped from central Minnesota and North Dakota Counties in the Red River Basin and in the Devil's Lake Basin, and westward to Montana (Barker and Mitchell 1977). *M. spicatum* L., as mapped by the Canadian Wildlife Service (1999) (based on Aiken 1981, Couch and Nelson 1985) shows *M. spicatum* advanced in 1985 to central Minnesota and eastern Montana. No specific records are available for the project area, but given the difficulties of identification, it may be in the Red River and Devil's Lake basins, or soon will be. Its identification or its arrival in these areas will not likely be related to the interbasin water transfer between these basins.

<u>Size and Potential Detection</u>

A number of milfoil species occur in the western United States and many of these species are very similar to each other in appearance. EWM looks so much like its native relative *Myriophyllum sibericum* (=*M. exalbescens* Fern.) that it was once thought to be a variety of that species. The scientific taxon *M. spicatum*, described and cataloged in 1753 by Linnaeus, denoted both the European and the North American forms. Fernald (1950) renamed the North American plant *M. exalbescens*, however other botanists did not fully embrace the specific epithet. Barker and Mitchell (1977) provided a distribution map for the species, "*M. spicatum* L. var. *exalbescens* (Fernald) Jepson". Aiken (1981) and Couch and Nelson (1985) regard *M. spicatum* and *M. exalbescens* as separate species. Many botanists continue to lump, rather than separate the forms, of which there may even be genetic intergrades. Often, even milfoil experts must rely on pigment or DNA analysis to distinguish milfoil species from each other.

<u>Movement and Dispersal Mechanisms</u>

Although EWM can potentially spread by both sexual and vegetative means, vegetative spread is considered the major method of reproduction. In Lake George, New York a young population of EWM averaged a seed set of 112 seeds per stalk. EWM seeds readily germinate in the laboratory and also germinated *in situ* in a study conducted in Lake George. Despite the high seed production, it is thought that germination of seed is not a significant factor in EWM reproduction. Seedlings have never been observed occurring naturally *in situ*, therefore colonization of new sites is mainly by vegetative fragments. During the growing season, the plant undergoes autofragmentation. The abscising fragments often develop roots at the nodes before separation from the parent plants. Fragments are also produced by wind and wave action and boating activities, with each fragment having the potential to develop into a new plant. Once introduced, EWM also may spread rapidly. In Currituck Sound, North Carolina, EWM was first reported in 1965 when approximately 40 hectares were densely infested and 200 to 400 hectares were lightly infested. A year later 3,200 hectares were heavily infested and 26,800 hectares had some milfoil plants. Nine years later, over 32,000 hectares were infested with EWM.

Ecological Roles and Economic Importance

EWM adversely impacts aquatic ecosystems by forming dense canopies that often shade out native vegetation. Monospecific stands of EWM provide poor habitat for waterfowl, fish, and other wildlife. Significant rates of plant sloughing and leaf turnover, as well as the decomposition of high biomass at the end of the growing season, increase the internal loading of phosphorus and nitrogen to the water column. Dense EWM mats alter water quality by raising pH, decreasing oxygen under the mats, and increasing temperature. EWM impacts power generation and irrigation by clogging dam trash racks and intake pipes. Stagnant water created by EWM mats provides good breeding grounds for mosquitoes. EWM interferes with recreational activities such as swimming, boating, fishing and water skiing. In Washington State, private and government sources spend about $1,000,000 per year on EWM control. Other states and provinces (Minnesota, Wisconsin, Vermont, New York, and British Columbia) spend similar amounts per year to control EWM infestations.

The above-noted negative impacts could also apply to many other species if they occur in dense monospecific stands, but most aquatic plants in healthy systems are precluded from forming such stands by competitors. It is the Eurasian species' ability to outcompete others and form monospecific growths that distinguish it from native species.

Control Methods

Westerdahl and Getsinger report excellent control with 2,4-D, diquat, diquat and complexed copper, endothall dipotassium salt, and endothall and complexed copper. They report good control with fluridone. In Washington, fluridone (brand name Sonar®) has been successfully used to eradicate EWM in Long Lake, Thurston County and in other western Washington lakes. To be effective, fluridone concentrations of 10-15 ppb must be maintained in the water column for 10 to 12 weeks. Follow-up diver surveillance and hand-pulling of surviving plants is essential to the success of this technique. Some eradication attempts with fluridone have had mixed success in Washington. Factors such as surface and ground water inflows and development of land forms of EWM all affect the success rate. The herbicide triclopyr is undergoing federal aquatic registration and holds great promise for EWM control. Unlike fluridone, triclopyr requires a short contact time (18 to 48 hours) and will selectively control EWM while leaving many native aquatic plants relatively unaffected.

Localized control (in swimming areas and around docks) can be achieved by covering the sediment with an opaque fabric which blocks light from the plants (bottom barriers or screens). Managers of reservoirs and some lake systems may have the ability to lower the water level as a method of managing aquatic plants. The Tennessee Valley Authority (TVA) uses both winter and summer water level draw downs as effective way of reducing EWM biomass. They find that a draw down of about 2 meters is effective in reducing excessive populations. Short-term dewatering for 2-3 days during period of freezing temperatures has been effective, but multiple exposures may improve control. A 1-week draw down of a large TVA impoundment in July 1983 desiccated about 810 hectares of EWM. A narrow, relatively weed-free band occurred after refilling and control effects extended into the following two growing seasons. In Washington, the

Bureau of Reclamation lowered the water level of Banks Lake in 1994 in an effort to manage EWM populations. The success of a drawdown on EWM is dependent on several factors such as degree of dessiccation (draw downs in rainy western Washington and Oregon are often ineffective), the composition of substrate (sand vs. clay), air temperature (the exposed sediments need to freeze down to 8-12 in.), and presence of snow.

Because this plant spreads readily through fragmentation, mechanical controls such as cutting, harvesting, and rotovation (underwater rototilling) should be used only when the extent of the infestation is such that all available niches have been filled. Using mechanical controls while the plant is still invading, will tend to enhance its rate of spread.

Rotovation: The British Columbia Ministry of Environment developed a barge mounted rototilling machine called a rotovator to remove EWM roots. Underwater tiller blades churn up to 8 inches into the sediment and dislodge buoyant EWM roots. Floating roots may then be collected from the water. Control with rotovation, generally extends 2 or more growing seasons.

Harvesting: Harvesting can be compared to underwater lawn mowing. Plants are cut generally 5 feet below the water's surface, collected by conveyer, and stored until disposal on land. Harvesting removes surfacing mats and creates open areas of water. However because of its rapid growth rate EWM generally needs to be harvested twice during the growing season.

Cutting: Cutting is similar to harvesting except cut plants are not picked up from the water by the cutting machine. Washington requires that cut plants be removed from the water.

Research into biocontrol methods has progressed in recent years, with many scientists and government agencies experimenting with imported herbivores and pathogens, including the following.

Insects: The United States Department of Agriculture in conjunction with the Army Corps of Engineers have carried out searches for EWM biological control agents in Pakistan, Bangladesh, China, Korea, and Yugoslavia. Several insects have been evaluated, including a number of pyralid moths and several stem-boring weevils. However, many of these insects were found to be non-specific to EWM or to offer little potential as effective biological control agents. In British Columbia, several insects were associated with EWM and a midge was investigated as a potential control agent. However, the midge proved to be extremely difficult to rear in the laboratory. The North American weevil, *Euhyrchiopsis lecontei* (Dietz) has been found associated with declining populations of EWM in northeastern North America. *Euhrychiopsis lecontei* has been found in Washington state feeding on both EWM and northern milfoil (*Myriophyllum sibericum*) plants. Studies have shown that this native weevil appears to be a milfoil specialist and will not feed on other macrophyte species. It can be easily raised in the laboratory and laboratory-reared weevils could be used to augment natural populations, as is being tried in Vermont and Wisconsin.

Grass Carp: Although triploid grass carp will eat EWM, it is not a highly palatable or preferred species. To achieve control of EWM generally means the total removal of more palatable native aquatic species before the grass carp will consume EWM. In situations where EWM is the only aquatic plant species in the lake, this may be acceptable. However, generally grass carp are not recommended for EWM control.

Plant Pathogens: Interest in pathogens of EWM was stimulated by extensive mortality of EWM in Lake Venice and the Northeast River, Maryland in the late 1960s. At that time, the declines (called Northeast Disease) were suspected to be caused by a pathogen, although no pathogens were ever isolated. However Northeast Disease stimulated research into the use of plant pathogens for biological control. The plant pathogenic fungus *Mycoleptodiscus terrestris* has been shown to significantly reduce EWM biomass in laboratory studies. A commercial biotechnology firm spent several years developing this fungus as a biological tool to control EWM, but was unable to achieve control of the plant in field settings. The US Army Corps of Engineers is continuing research on plant pathogens.

9. *Butomus umbellatus* flowering rush

Life History and Distribution

The introduced, invasive flowering rush (*Butomus umbellatus*) is the single species in the family Butomaceae, in North America. The Butomaceae are rhizomatous, perennial herbs, with bisexual, hypogynous flowers, occurring on paludal or aquatic sites. Perfect flowers are produced only on emergent specimens. Submersed specimens are sterile, but will begin to flower if water levels are lowered.

Plants typically occur in mud or fresh water 2 or more meters in depth. The species appears to proliferate in locations of fluctuating water levels, where seeds may occasionally find suitable exposed mud upon which to germinate. The noted sterility of submersed specimens reflects an ability to endure inundation for long periods, while directing energy from flowering to vegetative reproduction. Occurring in a variety off lacustrine, paludal and riverine fringe locations, the species shows high adaptability to variable flow and nutrient regimes. Haber (1997) reported on studies that showed a limitation of growth and increased plant mortality resulting from the application of high levels of nutrients. There is however no mention in the literature of salt tolerance.

Flowering rush, over-wintering as rhizomatous colonies or discrete tubers, emerges in spring. Seeds deposited during the previous fall germinate and, if able to grow above the ambient water level, will flower and produce seed. The insect-pollinated flowers not only express large numbers of seed but may also produce tiny bulblets, which serve as vegetative propagules, fall and establish themselves during that season.

Flowering rush is a native of Eurasia, occurring from Great Britain to China. Rootstocks have been used as famine food in China and as a staple in Russia (Freedman 1998). The presence of often toxic levels of calcium oxalate, however necessitate much needed preparation effort prior to eating. There have also been some reports of the species used whole as a vermifuge by Iroquois. The plant has been extensively used as an aquatic garden ornamental species and is commercially available from a number of distributors. The potential threat of this species to displace native species is however presumed to be high, considering its rapid expansion over the last century.

Flowering-rush was first observed in North America around 1897 in the Montreal region (Core 1941), but it was observed to be more widely distributed shortly after the turn of the century. From the main center around Montreal, flowering-rush spread to other sites in southeastern Ontario and downstream along the St. Lawrence. It has spread over the decades from Quebec eastward, down the St. Lawrence and westward to eastern Michigan (Stuckey 1968), to Minnesota (Anderson et al. 1974), and to eastern North Dakota (Godfread and Barker 1977). Haynes (Haynes 2000) shows its distribution in North America to extend form Nova Scotia to northern Idaho. Environment Canada maps its distribution to the southwestern coast of British Columbia and across Canada (Canadian Wildlife Service 1991, 1999), completing flowering rush's march from coast to coast in about 100 years.

This species occurs in at least two locations in the Sheyenne River Valley; downstream of Lake Ashtabula and at several sites in the upper Red River Basin in Minnesota. (FNA 2000, Godfread and Barker 1977).

Size and Potential Detection

The species can take two forms depending on whether it grows in exposed mud/shallow water or deeper water. The stiffly erect, 3 mm wide leaves of the emergent plant often exceeds 1 m in height. The leaves of submersed specimens may approach 3 m in length, and become limp and ribbon-like when fully inundated.

Movement and Dispersal Mechanisms

The rapid rate of colonization is unlikely to be the result of natural propagation mechanisms alone. Flowering-rush has frequently been deliberately transported to new sites. Zenkert (1960) relates the case of a transplantation, in 1948, of several plants from a small colony about west of Port Colborne, Welland (now Niagara) County, to Millers Creek near the Niagara River opposite Grand Island. Such anthropogenic movements have occurred many times as people transplanted this showy aquatic to various sites in the Great Lakes region and beyond. Its recognition in a new area generally follows the observation of large monotypic stands, where an intentional transplanting has quickly gotten out of hand. Distribution in North America is generally between 40 and 53 degrees north latitude. The main population center remains along the St. Lawrence River.

Vegetative propagation is extremely important to the spread of this species. Creeping rhizomes allow expansion of existing stands. The vegetative vigor of rhizomes compensates for the lack of seed production during inundation. The floating, deciduous tubers produced late in the growing season, provide an important means for migration of the species, particularly by flowing water transport.

Ecological and Economic Importance

Flowering rush appears to occasionally form dense, monotypic stands, crowding out such beneficial plants as wild rice, reducing local diversity and degrading wildlife habitat (although the tuber may be sometimes used for forage). The species may become problematic in swimming and fishing areas by physically blocking access to shallow water areas. Costs for control of this species are not distinguished in the literature from control efforts for other aquatic weeds.

Little information is available on attempts to control the spread of flowering-rush. Because of its ecological plasticity and considerable reproductive capacity, it is able to invade natural habitats. One means of controlling its spread into new watersheds is based on generating public awareness of the plant's ability to spread aggressively once introduced. Many sites of current establishment are the result of deliberate transplantation or seeding.

Control Methods

The Canadian Wildlife Service (1999) notes that there have been no reported, successful attempts to control or eradicate flowering rush with herbicides, in the United States or Canada. The Minnesota Department of Natural Resources, however suggests use of 2,4D, Endothall and Diquat on emergent specimens, but does not report its efficacy. The Vermont Department of Environmental Conservation (VDEC, 1998) reports only very limited success with chemical controls, perhaps due to the inability of the chemicals to access the rootstock and deciduous tubers.

Azimsulfuron (DPX-A8947) has been studied for its effectiveness in controlling common weeds in rice fields of southern Europe. Azimsulfuron was found to be an effective control for a broad range of species including *B. umbellatus*. The studies also showed that Azimsulfuron had favorable environmental fate characteristics and toxicological properties.

Mechanical harvesting and rotovation have been used by reservoir managers in Vermont and Minnesota (VDEC 1998), with some degree of seasonal control. Repeated cuttings are necessary to prevent spread or re-colonization. Given rhizomatous growth and the marked capability for vegetation propagation, mechanical controls may increase the density and rate of propagule dispersion. Chopping the rhizome would certainly enhance propagation, since this is the primary means for propagating the ornamental specimen. Either complete desiccation of site soils or deep inundation for prolonged periods may limit the species. Seasonal desiccation followed by flooding will benefit seedling establishment. For example, a particularly dramatic expansion of colonies of flowering-rush in 1931, a year of exceptionally low water level along the St. Lawrence, was reported by Frère Marie-Victorin (Haber 1997).

There have been no reported studies to assess the effects of native vegetation on limiting colonization by flowering rush (Staniforth and Frego 1980, Canadian Wildlife Service 1999). There were no studies found reporting the use of insect, fish or plant pathogens to control this species. The presence of calcium oxalate in tubers and the presence of latex compounds in leaf vacuoles suggests that most wildlife would avoid ingestion of flowering rush.

10. *Hydrilla verticillata* - Hydrilla

Life History and Distribution

Hydrilla verticillata is a member of the Hydrocharitaceae family. It closely resembles other members of this family such as *Elodea canadensis* (native to North America) and *Egeria densa* (native to South America, though established in many western lakes). Several members of this family are popular with the aquarium and nursery industry because they are hardy, tolerant plants. Consequently, some have become severe pest problems where introduced to waters outside their native range.

Hydrilla is a submersed, freshwater perennial herb, generally rooted on the bottom in depths of greater to 20 feet where water clarity is good. It is found in lakes, rivers, reservoirs, ponds, and ditches. It tends to form monospecific stands that can cover hundreds of acres.

Hydrilla grows rooted to the bottom, submersed in either still or flowing water. The depth of growth depends on the water clarity and substrate type. The dioecious plants tend to form long stems until they near the water surface at which point the stems branch and form dense mats. The monoecious plants tend to be more delicate and branch at the sediment instead. They then form many stems, which rise to the surface and fill the entire water column.

Hydrilla reproduces sexually by forming morphologically distinct male and female flowers, but also can spread vegetatively via underground rhizomes and above ground stolons. It can also form vegetative propagules called tubers and turions in the fall as dormant over-wintering structures. These may remain dormant yet viable for several years in the sediment.

Hydrilla is native to parts of Asia, Africa, and Australia. A female dioecious plant was introduced into Florida in the mid-to-late 1950s and dioecious hydrilla has since spread throughout the southeastern states including Georgia, Alabama, Virginia, and South Carolina. Hydrilla is found as far west as Texas and California. Monoecious hydrilla is found in lakes in North Carolina and the Potomac River near Washington D.C. and also has been reported in Maryland and Delaware. The monoecious plants in found in Washington State in 1995 represent the northernmost occurrence of hydrilla in the United States. Hydrilla is not known to occur in Oregon, Idaho, Montana, or British Columbia.

There are no records of hydrilla for the region or project area. Its apparent adaptability and progressive migration into more northerly climates suggest it could become problematic if established in the Red River drainage.

Size and Potential Detection

Hydrilla grows from the benthic sediment to the water's surface, so plant size depends on water depth. Stem lengths of up to 30 feet have been recorded in clear Florida water, exceptionally favorable habitat.

Hydrilla verticillata is the only species in this genus, yet it shares characteristics with other genera in its family. Because of this, correct identification is imperative. Another complicating factor is that hydrilla can be either monoecious (both male and female flowers on the same plant) or dioecious (male and female flowers on different plants). Each variety of hydrilla has some unique growth characteristics. It is the monoecious type that has been found in Washington State and in Northern California. Dioecious hydrilla has also been found at numerous sites in California.

Movement and Dispersal Mechanisms

Hydrilla was first introduced into North America in the mid to late fifties by the aquarium trade. California officials have also traced hydrilla infestations to shipments of mail order water lilies. Once introduced and established, hydrilla is easily spread through boating and fishing activities and by waterfowl. Hydrilla tubers are readily consumed and regurgitated tubers have been shown to be viable.

Ecological Roles and Economic Importance

In areas of North America where hydrilla has become established, it has major detrimental impacts on water use. Hydrilla adversely affects aquatic ecosystems by forming dense canopies that often shade out native vegetation. Extensive monospecific stands of can provide poor habitat for fish and other wildlife, although the plant is eaten by waterfowl and is considered an important food source by some biologists. While dense vegetation may contain large numbers of fish, density levels obtained by plant species such as hydrilla may support few or no harvestable-sized sport fishes. Dense mats alter water quality by raising pH, decreasing oxygen under the mats, and increasing temperature. Stagnant water created by hydrilla mats provides good breeding grounds for mosquitoes.

Hydrilla interferes with recreational activities such as swimming, boating, fishing and water skiing. In the Western states, hydrilla has the potential to impact power generation, irrigation, and water delivery systems by clogging dam trash racks and intake pipes. In areas where hydrilla, EWM, and Brazilian elodea coexist, hydrilla outcompetes these other two noxious species. Hydrilla has the potential to cause greater adverse impacts to aquatic ecosystems than either EWM or Brazilian elodea, both severe problem species in some Western states. In states where hydrilla has become established, millions of dollars are spent each year for management activities.

Hydrilla has infested over 65,000 acres of Florida's lakes, rivers, streams, drainage and irrigation canals. Florida managers regard hydrilla as their most serious aquatic pest, despite nearly $50 million spent managing hydrilla during the 1980s. Approximately half a million dollars is spent each year for hydrilla control activities in North Carolina. California has been committed to eradicating hydrilla since its first appearance in the state in 1976. However, whenever eradicated from one lake, the species shows up in others. Since the 1976 discovery, waters in at least 15 California counties have become infested with hydrilla.

Management

Scientific research and 30 years of practical experience by aquatic plant managers using herbicides, biological agents, mechanical removal, and physical habitat manipulation have produced relatively successful management programs in Florida and other states. However, in spite of long-term intensive management efforts, hydrilla is still a major weed problem in the states where it has become well established. Hydrilla's great reproductive potential, especially via tubers and turions, creates the greatest problem for aquatic plant managers. It has been shown that one tuber can lead to the production of over 5,000 new tubers per square meter. The tubers and turions can withstand ice cover, drying, ingestion and regurgitation by waterfowl, and herbicides.

Hydrilla also has several physiological and morphological adaptations, which allow it to outcompete native aquatic vegetation. It can grow at lower light intensities than many other plants, which makes it difficult to shade out, and allows it to grow for longer periods during the day. It can absorb carbon from the water more efficiently than other plants, so can continue to thrive during the summer when carbon can become limiting. It can also store extra phosphorus, so when lack of this nutrient limits the growth of other plants, hydrilla can use what it has stored. It is tolerant of a wide range of water conditions, though water quality and sediment density can influence tuber production and growth. It will thrive in flowing water as well as still water.

Studies have shown that it actually grows faster in flowing water. It will tolerate salinity of up to 9 -10 parts per thousand, so could encroach upon the outer limits of estuaries.

Control Methods

There are three EPA-registered herbicides effective against hydrilla growth that are permitted for use in Washington. These are fluridone (Sonar®), endothall (Aquathal®), and copper compounds. Fluridone is a systemic herbicide that has proven effective against hydrilla in Florida and other states. The drawbacks to using fluridone include its high cost, slow-action, and non-selectivity toward other macrophyte species. However, it is the herbicide of choice. Endothall, a fast-acting contact herbicide, is used when immediate control of vegetation is needed. Copper compounds are often used in conjunction with endothall applications, although copper by itself exhibits herbicidal action against hydrilla. Copper is also used for its algicidal properties when heavy periphytic growth on the hydrilla may interfere herbicide uptake. These herbicides do not affect hydrilla seeds, tubers, and turions and repeated applications are needed to control hydrilla regrowth.

Response to Cultural Methods. Localized control (in swimming areas and around docks) can be achieved by covering the sediment with a opaque fabric which blocks light from the plants. Managers of reservoirs and some lake systems may have the ability to lower the water level as a method of managing aquatic plants. This technique is sometimes successful in areas where the hydrosoil can thoroughly desiccate.

Response to Mechanical Methods. Because this plant spreads readily through fragmentation, mechanical controls such as cutting and harvesting should be used only when the extent of the infestation is such that all available niches have been filled. Using mechanical controls while the plant is still invading, will tend to enhance its rate of spread.

In Florida, specially designed aquatic plant harvesters are used to cut and collect hydrilla from waterways. Hydrilla harvesting is mainly performed to open boat lanes through hydrilla beds for navigation. Because hydrilla produces more biomass per square meter than most aquatic plants, the cost of harvesting hydrilla is generally higher than for harvesting other nuisance species such as EWM. Harvesting costs on the Potomac River were about $1,200 per acre (costs for harvesting milfoil in Washington average $600 to 800 per acre).

Worldwide surveys for natural hydrilla enemies were begun in 1981 in a cooperative study between the University of Florida, the United States Department of Agriculture, and the U.S. Army Corps of Engineers. A number of insects were identified, quarantined and tested, and eventually released in Florida and other states. Results from these insect releases are still being evaluated. Although they have access to many biocontrol agents, grass carp have been deemed the most effective biological control for hydrilla by Florida lake managers.

12. *Lythrum salicaria* - Purple Loosestrife

Life History and Distribution

Purple loosestrife is a perennial, emergent aquatic plant that grows from a persistent tap root and spreading root stock. When mature the taproot and major root branches become thick and woody. Purple loosestrife tolerates a broad pH range, with successful germination occurring between pH of 4.0 and 9.1 (Shamsi and Whitehead 1973 as cited in Thompson et al. 1987).

Purple loosestrife also spreads vegetatively. Buried stems harbor adventitious buds with the ability to produce shoots or roots. Disturbance to the plant, such as stomping and breaking underground stems, or breaking off stems or roots during incomplete plant removal, does initiate bud growth.

Purple loosestrife occurs in freshwater and brackish wetlands. It is a successful colonizer and potential invader of any wet, disturbed sites in North America. Associated species include cattails, rushes, sedges, and reeds.

Europe and Asia are thought to be the geographic origin of purple loosestrife. In the mid to late 1800's, *L. salicaria* traveled to northeastern U.S. port cities as ship ballast from European tidal flats. When this ballast was dumped for the return trip to Europe, a major seed source remained along the eastern seaboard (Stuckey 1980 as cited in Wilcox 1989; Thompson et al. 1987 as cited in Wilcox 1989). For the next 100 years it was a pioneer species while it acclimated to the northeastern seaboard and the St. Lawrence Seaway (Henderson 1987).

Purple loosestrife is found in the lower Sheyenne Basin in North Dakota and in the Red River Basin in northwestern Minnesota in Marsh, Sand and Grand Marias Creeks (USGS 1999, Barker and Mitchell 1977).

<u>Size and Potential Detection</u>

As many as 30-50 herbaceous, erect, annual stems rise to about nine feet tall from a persistent perennial tap root and spreading rootstock. Short, slender branches spread out to form a crown five feet wide on established plants (Thompson et al. 1987).

Lythrum salicaria is believed to be a well defined, albeit variable, species (Thompson et al. 1987) that is readily identified in the field. *Lythrum* is one of 22 genera of the loosestrife family, Lythraceae. Twelve species of this family are found in the continental United States (Shinners 1953) with three species being exotic. They are *Lythrum hyssopifolia*, *L. salicaria*, and *L. virgatum*. Distinguishing the three species can be difficult.

<u>Movement and Dispersal Mechanisms</u>

The lack of energy reserves in the seed suggests that viability in the field would not last more than a few weeks (Thompson et al. 1987), but a mature plant can produce 2.7 million thin-walled, flat seeds. Water dispersal includes floating seedlings and floating ungerminated seeds. The seeds are small and light enough (weight 0.5 - 0.6 mg) for wind dispersal, but the evidence points toward minimal wind distribution. Most dispersal is down slope, and not downwind. Seedling densities sharply fall within 34 feet of the parent plant. Other distribution methods include transport through wetland mud by animals, humans, boats, or vehicles. Spread also occurs when seeds are eaten (Thompson et al. 1987).

A survey of an east-west highway corridor in New York State (I-90) showed a purple loosestrife population density gradient that indicates an east-to-west migration route. This research supports both that loosestrife worked its way out west from the eastern states, and that the modern highway system, with disturbance and seed-carrying capacity, plays a part of that distribution. This is a short-distance migration. The wind currents created by traffic and the disturbance created from highway construction and maintenance moves purple loosestrife populations through nearby waterways or drainage systems (Wilcox 1989).

Ecological Roles and Economic Importance

Beneficial: Beekeepers consider the late season flowers of purple loosestrife as a source of nectar and pollen for over wintering colonies of bees. (Pellet 1977, Hayes 1979 as cited in Malecki 1992). An estimated loss of $1.3 million in honey sales in 19 states (over the next 20 years) is attributable to purple loosestrife control (Thompson et al. 1987). However, if native wetland plants are allowed to reestablish habitat, they would once again provide replacement forage for bees (Malecki 1992). As a horticultural plant, purple loosestrife is familiar to gardeners worldwide. During the mid 1900's the nursery industry developed and sold varieties and cultivars thought to be sterile (Lindgren and Clay 1993). Disagreement and confusion over infertility and taxonomy questions led to requests from the Minnesota nursery industry to stop producing non-native *Lythrum* varieties (Rendall 1986 as cited in Malecki 1992).

Medicinal uses for purple loosestrife date back to the 1st century (Stevens 1963 as cited in Thompson 1987). The generic name, *Lythrum*, is derived from the Greek root for blood, and herbal references mention the astringent or styptic properties. Tonics made from flowering branches, leaves and roots treated ailments that included dysentery, internal and external bleeding and healing of wounds and ulcers (Thompson et al. 1987).

The red-winged blackbird will nest in purple loosestrife stands, because the long-billed marsh wren, the major factor in red-winged blackbird nesting mortality, avoids purple loosestrife. Purple loosestrife seeds are not considered part of the diet of the red-winged blackbird (Balogh 1986).

Detrimental: *Lythrum salicaria* is a listed noxious weed in several states including Illinois, Minnesota, Ohio, Wisconsin, and Washington (Malecki 1992). In Washington state, purple loosestrife was placed on the Washington State Department of Agriculture Quarantine list under Wetland and Aquatic Weeds in 1991. The sale of all hybrids and cultivars is also prohibited.

The negative impact from purple loosestrife establishment in wetland habitat far outweighs any economic gain from horticultural or medicinal uses (Blossey and Schroeder 1992, Thompson et al. 1987). Purple loosestrife is invasive and competitive and undesirable to native wildlife, either as habitat or food. It can quickly adapt to environmental changes and expand its range to replace native plants used for ground cover, food, or nesting material. The physical structure of purple loosestrife provides very poor cover for nesting ducks (Timmerman 1992). Threatened and endangered species, including plants in Massachusetts and New York and the bog turtle in the northeastern U.S., are impacted by monotypic stands of purple loosestrife that replace native vegetation. Agriculture is also impacted by a loss of wild meadows, hay meadows, and wetland pastures. While not a threat to cultivated crop lands, purple loosestrife is raising concern in areas where wild rice is cultivated in northern California (Blossey and Schroeder 1992). When purple loosestrife invades irrigation systems, economic losses to agriculture can exceed $2.6 million annually (Malecki 1992).

Control. Methods

Although a non-selective herbicide, glyphosate (Rodeo) provides good control. Triclopyr and 2,4-D are also effective in controlling purple loosestrife.

Cutting alone is not a control option for purple loosestrife. Shoots and adventitious roots will develop. Cutting late in the season reduced shoot production more than mid summer cutting, indicating that carbohydrate reserves could not be restored for next years growth. Flooding is only recommended for large infestations because of the problems associated with maintaining constant water levels and because of the negative impacts to native plants (Malecki and Rawinski 1985). Black plastic covering did not kill the roots of mature plants in test plots, although it did slow down growth and seed production. However, root crowns did die in plots where heavy litter from mowing remained covered until June. More study is needed (WDFW 1992).

In 1992 three beetle species were released in Washington. Their damaging impact on purple loosestrife populations was evident in the Winchester Wasteway area of Grant County in 1997. Biological control agents may provide the long term success in controlling this noxious weed. *Galerucella calmariensis* and G. pusilla - are both leaf-feeding chrysomelids. These beetles defoliate, and attack the terminal bud area, drastically reducing seed production. The mortality rate to purple loosestrife seedlings is high. Evidence of *Galerucella* ssp. damage are round holes in the leaves. Four to six eggs are laid on the stems, axils, or leaf underside. The larvae feed constantly on the leaf underside, leaving only the thin cuticle layer on the top of the leaf. By 1996 populations of *Galerucella* ssp. visibly impacted purple loosestrife stands in the Winchester Wasteway.

Hylobius transversovittatus is a root-mining weevil that also eats leaves. This beetle eats from the leaf margins, working inward. The female crawls to the lower two to three inches of the stem then bores a hole to the pithy area of the stem, where one to three eggs are laid daily from July to September. Or, the female will dig through the soil to the root, and lay eggs in the soil near the root. The larvae then work their way to the root. *H. transversovittatus* damage is done when xylem and phloem tissue are severed, and the carbohydrate reserves in the root are depleted. Plant size is greatly reduced because of these depleted energy reserves in the root. The larvae evidence is seen in the zig-zag patterns in the root.

Several other biological control agents are being studied for release: *Nanophyes marmoratus* is a seed eating beetle. Young adults feed on new leaves on shoot tips, later feeding on the flowers and closed flower buds. Sixty to one hundred eggs are laid in the immature flower bud. Seed production is reduced by 60 %. There were two test sites releases in 1996. *N. marmoratus* is being propagated at Wasington State University in Pullman to increase their numbers. A possible field release is planned in 1998. N. brevis is another seed beetle that attacks the seed capsules. They have not been released in the United States yet (Piper 1997). *N. brevis* and *Bayeriola salicariae* were studied and screened between 1990 and 1992 (Blossey and Schroeder 1992).

3.5.1.3 Biology of PBOC: Free-living Invertebrates and Protozoa

Information on the invertebrate taxa described below is largely taken from Pennak (1989) and Thorp and Covich (1991), unless otherwise noted.

Taxon name: protozoa*
Common name: protozoa
Taxonomy: Kingdom Protista (a.k.a. Protoctista); Subkingdom Protozoa*
* some authors consider "protozoa" a non-taxonomic term of convenience

Life history and distribution.

Protozoa are a highly diverse taxonomic group. They contain a wide variety of morphologic and physiologic adaptations as well as life history strategies. Protozoa are all single-celled organisms, although some form colonies or associations of cells which appear superficially to be multi-celled organisms.

Because protozoa are single-celled, differences between protozoans are based on the presence of external flagella or cilia for locomotion and internal "organs" such as chromatophores, different types of vacuoles, chloroplasts and so on. Protozoa may be parasitic or free-living. Parasitic species have inestimable effects on the well-being of humankind (and other species), with many causing diseases, but parasitic protozoa are not addressed here.

Free-living protozoa generally do not have a major impact on human health and/or water quality. About 500 genera of free-living protozoa are known to occur in the fresh waters of the U.S. (Pennak 1989), and most are thought to be cosmopolitan in distribution. Most can form a dry cyst that is readily transported by wind, so similar habitats around the world are likely to support similar species assemblages (Cairns and Ruthven 1972). Local distribution is most likely governed by environmental conditions, such as light availability, temperature, dissolved oxygen, acidity, and other factors.

Size and Potential Detection.

As single-celled organisms, they are almost all microscopic (30 μm to 300 μm). Some are as small as 5 μm and some as large as 5 mm (Pennak 1989). Detection can be difficult, because microscopic examination of large numbers of water samples by trained experts is generally necessary to detect any given genus or species.

Movement and Dispersal Mechanisms.

Means of locomotion vary widely in protozoa. Flagellates such as dinoflagellates move by whipping their flagella back and forth in the water. Other genera use pseudopodia to move by streaming movements of the body (e.g. amoeba). Others use beating of cilia to move. Some genera of protozoa are normally sessile, but metamorphose into a "swarmer" stage where they move to new locations (Pennak 1989). In freshwaters, protozoa are subject to passive dispersal by water movements, being unable to actively migrate over distances.

Dispersal is thought to be primarily by wind transport of the dry cyst stage. Many protozoa genera are so widespread that a culture of protozoa can be grown in an aquarium from any water sample or even cut hay, grass, or aquatic vegetation. They quickly colonize new habitats, as shown by Maguire's (1977) study of new volcanic islands. Because of these dispersal capabilities, protozoa species are usually considered ubiquitous, although regional variations of the same species can be found. For example, the "species" *Paramecium aurelia* has been found to be a complex of sister species with different geographical ranges (Cairns and Ruthven 1972).

Ecological Roles.

Despite widespread research on protozoan taxonomy, cell biology, and human health impacts, there is little known about their ecology in fresh waters (Pennak 1989). Many of the better-studied organisms are the parasitic species. Some free-living protozoa are known to grow to great abundance in municipal water supplies in rivers, lakes, and reservoirs, such as *Dinobryon*, *Volvox, Chlamydomonas*, and others. Protozoa may play an important role in aquatic food chains, by removing fine particulate living and dead material on the one hand and providing food to small metazoans on the other hand.

Species name: *Bythotrephes cederstroemi*
Common name: spiny water flea
Taxonomy: Phylum Arthropoda; Class Crustacea; Order Cladocera

<u>General Biology</u>

B. cederstroemi is a predatory cladoceran that feeds on other zooplankton. Spiny water flea gets its name from a long spine extending from its tail that greatly increases its body length and deters grazing by small fishes. This anatomical characteristic gives the species a competitive advantage over native cladocera and other zooplankton (Caceres and Lehman 2000).

B. cederstroemi also has a rapid reproduction rate. This species can produce a new generation via parthenogenesis (asexual reproduction) in less than two weeks. As in all Cladocera species, the female carries her young on her back in a balloon-like brood pouch, which can carry either developing embryos or resting eggs. Usually the species produces by pathogenesis, with the female producing from one to ten eggs, which are genetic replicas of the mother. Sexual reproduction occurs when environmental conditions are unfavorable for asexual reproduction.

The spiny water flea invaded the Great Lakes during the 1980's. It has established successfully in several of the Great Lakes and appears to now be a permanent part of the zooplankton community. Research on the biological characteristics of this species suggest it could pose a threat to small inland lake ecosystems as well (Caceres and Lehman 2001). It does not currently exist in the Devils Lake, Red River or Lake Winnipeg basins.

B. cederstroemi.are native to Europe. In North America it is only known in the Great Lakes region, so far. It has established populations in all of the Great Lakes. The species is planktonic, requiring open water for their adult life stage. The resting eggs can survive in ship ballast water, which is likely how they were transported to the Great Lakes originally.

<u>Size and Potential Detection</u>

This species is very large for a cladoceran. It's average length is 0.4 inches, making it visible to the naked eye (Caceres and Lehman, 2001). Any plankton sampling gear designed for freshwater should capture this species.

<u>Movement and Dispersal Mechanisms</u>

Aquatic dispersal is thought to be passive, i.e. it is moved by water currents. Transoceanic dispersal is believed to be effected by been accidental transport in ship ballast water. This species is has not yet been found in smaller inland lakes in the Great Lakes basin, so overland dispersal abilities have not yet been determined. Like other Cladocera, it probably has some capacity to disperse among water bodies via larger animals and/or wind, as discussed in detail below.

<u>Ecological Roles</u>

Spiny water fleas eat other small zooplankton, acting to transfer energy from primary consumer (small herbivorous zooplankton) to larger fish species. In their native habitats of Europe, many fish prefer *Bythotrephes* as a food source. However in the Great Lakes, its long spine deters the native small fishes from grazing upon it. Because spiny water flea is not heavily grazed upon, it is capable of greatly reducing the abundance of small cladoceran species that it eats (Lieder 1991). *Bythotrephes* competes with young fish for zooplankton, and may also reduce the food source available for those fish.

Species Name: *Cipangopaludina chinensis*
Common name: Chinese mystery snail or Japanese trap door snail
Taxonomy: Phylum Mollusca; Class Gastropoda; Family Viviparidae

<u>Description</u>

The Chinese mystery snail is a small gastropod that was introduced to North America from Asia. The snail originally occupied China and Southeast Asia, and was brought to the U.S. by the aquarium trade. First reported in waters of North America in 1892 in San Francisco, it has since spread to many other areas of the US., including the St. Croix River (Minnesota/Wisconsin border), Iowa (Barnhart 1978) and the east coast. It is not known to currently exist in the Devils Lake, Red River or Lake Winnipeg basins.

Chinese mystery snails are often found partially buried in the mud or silt of lakes, ditches, rice fields and other wet areas (Aguirre and Poss 2001). They prefer quiet water where there is some vegetation and mud substrate.

Like many snails, this species can serve as a vector for various parasites and diseases that may infect human beings. It has not been reported to be particularly invasive in any of the literature.

<u>Size and Potential Detection</u>

The snails are readily detected. They reach a maximum length of 65 mm in length. Identification can be performed by professionals or informed amateurs with little difficulty, largely because these snails reach such large sizes relative to native species.

<u>Movement and Dispersal Mechanisms</u>

Gastropods can move by use of a muscular foot (Pennak 1989). Some are capable of traversing terrestrial habitats, but the Viviparidae are not known to have this capability. It is likely that juveniles have some capacity for passive dispersal on birds and other vertebrates, but this has not been shown to occur for this species. Given their rather limited overland dispersal abilities, these snails are presumed to have spread across North America primarily by human transport for the aquarium trade. Their large size has allowed them to be competetive in natural systems, expanding their habitat areas within waters into which they are introduced.

<u>Ecological Roles</u>

There is little information available on these snails' ecological role in North America, despite their being first reported in N. America in 1892 by Wood. Aquatic snails, in general, are grazers on algae and biofilm communities (aufwuchs, periphyton) adhering to macrophyte and benthic surfaces, but there are exceptions to this rule among the gastropods, including many vegetation feeders. Many snails are opportunistic, but are not truly omnivorous because they are not known to scavenge dead animal tissue. As prey, snails are important to crayfish, leeches, certain aquatic insects, and some birds.

These snails, and many others, are known to serve as vectors for certain diseases that can infect human beings and many other animals. They serve as an intermediary host for several trematode flatworm parasites, such as the trematode that causes swimmer's itch when it leaves a snail and finds a human instead of its proper definitive host, a merganser.

Species name: *Dreissena polymorpha*
Common name: zebra mussel
Taxonomy: Phylum Mollusca; Class Bivalvia; Order Pelycypoda; Family Dreissenidae

Life History and Distribution.

Zebra mussels have attracted much attention because they first invaded the Great Lakes from their Eurasian home rather recently, and their spread through the lakes has been rapid, dramatic, and well-studied. The invasion of these mussels into new waters is greatly feared because they have great capacity to cause ecological and economic damage (Jensen 2000, Minnesota Sea Grant 2001).

Zebra mussels use external fertilization by broadcasting gametes into the water, thus they are exclusively sexually reproducing animals. This is rarely a limitation on reproduction, however, because they congregate in clusters so "mates" are generally readily available. Fertilized eggs immediately begin development, and hatch into a larval stage, called a veliger, that remains suspended in the water column for a short time. The veligers settle on a substrate and immediately metamorphose into an adult mussel stage. Much of the success of zebra mussels depends on their small adult size which require a short development time, relative to many other mussel species. This allows them to quickly produce new generations of adults, which become affixed to any hard substrate, including rocks, human-made structures, the shells of other animals (molluscs and decapod crustaceans), and plant stems, to a lesser extent. When juvenile zebra mussels attach to the shells of other zebra mussels, they begin to form a cluster called a "druse". These clusters can grow in size by the addition of other mussels, and can effectively colonize unstable substrates, such as sand, by rolling on the bottom as waves push them around.

This species is a Eurasian native that invaded North America via shipping in the St. Lawrence seaway and the Great Lakes. It is presently common in the Great Lakes, but is rare in inland waters. Its range is closest to the DL and RR basins at the western edge of Lake Superior in Minnesota. Thus, it is likely to colonize the RRB before spreading to the DLB, unless carried directly to the DLB by human activity.

Zebra mussels are most successful in waters with hard substrates and an abundance of suspended food (e.g. algae, small zooplankton, and particulate organic matter). The species is native to the brackish waters of the Black Sea, so the salinity conditions of the DLB are unlikely to hinder its success, should it disperse there.

Zebra mussels are capable of rapid population growth, outcompeting native mussel species, and they can dramatically affect water clarity and plankton abundance through their filter-feeding activity.

Size and Potential Detection

Veligers are particularly small, and are not readily detected using standard macroinvertebrate sampling methods. Plankton sampling methods capture them, but they may occur in low enough abundances that they are not often collected in plankton tows. Adults, on the other hand, are large and stationary, so they are easily detected by appropriate sampling methods. However, because they remain firmly affixed to substrates, standard macroinvertebrate sampling methods may miss them completely. They are most easily detected through SCUBA diving observation, or fortuitous collection of individuals affixed to other animals (e.g. crayfish) or plants that are collected in general surveys, or through standard inspection/maintenance procedures for water-intakes relateed to industrial or water-supply operations.

Movement and Dispersal Mechanisms

Veliger larvae are planktonic, so they are passively dispersed through water currents. Adults are non-motile. The recent spread of zebra mussels has been a result of human-created pathways, which include being carried in ship ballast water and on surfaces and in bilge water of recreational boats.

Ecological Roles

Zebra mussels play an important role in systems in which they are found. They have dramatic effects as consumers of plankton, affecting water clarity and transferring much biomass from the water column to the benthos. They provide food sources and habitat for many benthic invertebrates, and probably algae. However, they are not preyed upon by many species, so they are not as important in the typical lake food chain as an energy transfer to fishes.

Taxon name: Phylum Rotifera
Common name: rotifers

Life History and Distribution

Rotifers are ubiquitous in, and characteristic of, freshwater environments, often forming a very large proportion of the planktonic, vegetational, and benthic meiofauna. They occur in all freshwater habitats, including large lakes, small puddles, damp mosses, and just about any rainwater-filled container left undrained for a few days. They are the most abundant freshwater planktonic group in most environments.

Rotifer reproduction occurs both sexually and asexually. Some species are apparently exclusively parthenogenetic. For the rest, males and sexual females only occur during periods of environmental change. The resulting fertilized eggs in some species are thick-walled and resistant to adverse environmental conditions, and are the typical over-wintering stage.

Rotifers may produce anywhere from 20 to 40 or more generations per year, with mean clutch sizes ranging from 3.6 to 45.4 eggs in species that have been studied. All eggs, sexual or asexual, hatch into a small juvenile that grows rapidly without molting. Lifespan varies widely from less than a week to 6 weeks, depending on species and environmental conditions.

Most species are very widespread, even globally cosmopolitan, largely because of their highly affective dispersal mechanisms. Known habitat preferences and geographic distributions of all DLB taxa identified in this study are listed in Table 10.

Most species show preferences for littoral or limnetic habitats, but microhabitat specificity is rare. The majority of rotifers are found in the littoral zone of freshwater lakes and ponds, although about 100 species are limnetic. Some species are sessile, attached to a stable substrate such as submergent plants. A few species occur in brackish to salt water.

Size and Potential Detection

Rotifers are metazoans, but they are within the size range of the larger protozoans, usually from 100 um to 500 um, with some exceptions. This size range categorizes rotifers as "meiofauna", organisms that pass through a 500 um sieve, but are retained by a 63 um sieve. Many biologists are not accustomed to working with meiofauna, so detection of rotifer species may require meiofauna specialists. Provided these considerations are taken, standard plankton collection methods generally capture limnetic rotifer species, but attention must be paid to vegetated littoral areas, where research is more difficult and has a less developed history and methodology. Among the littoral fauna, sessile species are least likely to be detected because they attach to plants and other substrates so sampling methods may miss them, or investigators may not examine such substrates. Special sampling procedures must be employed to ensure detection of species.

Movement and Dispersal Mechanisms

Water-borne dispersal over large distances is largely due to currents. Over land dispersal is not entirely understood, though it clearly occurs constantly, given the widespread distribution of most species. Only a small minority of species are known to produce resting, dessication-resistant eggs that can be blown by the wind. Additionally, some rotifers of the bdelloid order can transform themselves into an adult resting stage that can be wind-dispersed. The remainder of species may passively disperse via bird and mammal transport.

Ecological Roles

Most rotifers are omnivorous eating all organic matter, living or not, that is small enough to be captured and ingested (small algae and protozoa, small particulate matter). A few species are predators on other rotifer species and smaller instars of crustaceans and any other animal they can capture. Rotifers are prey for many other small invertebrates and for larval fishes.

Potential rotifers of concern

Rotifers have highly effective dispersal mechanisms including wind dispersal of resting eggs and dessicated bdelloids and transport via birds and other animals. As a result of their pervasive dispersal, it is likely that rotifer species found in Devils Lake have already been widely dispersed throughout the region. For this reason no rotifers were listed as Potential Biota of Concern (PBOC).

Differences in rotifer species composition in Devils Lake and Lake Winnipeg are probably partially due to differences in salinity, as rotifers are known to be sensitive to water chemistry. Differences between Devils Lake and the Sheyenne and Red Rivers are very likely the result of factors related to the lotic conditions of the rivers. Planktonic species in general do not persist in rivers for long distances from source lakes or reservoirs (Allan 1995, Ward 1975). Large zooplankton, such as *Daphnia* sp. are lost from the drift with increasing distance downstream from lakes or reservoirs. Smaller rotifers tend to be the most abundant group of zooplankton in lotic (running water) ecosystems (Allan 1995). Due to the increased velocity of streamflow and resultant short residence time of water in streams, many of the rotifers found in Devils Lake are likely to be absent or much less abundant in lotic ecosystems such as the Sheyenne and Red Rivers.

Of the rotifers found in Devils Lake, *Keratella cochlearis*, *K. quadrata*, *Filinia longiseta*, and *Asplanchna sp.* are known to be some of the most abundant plankton species nation-wide. *Brachionus sp.* are also fairly common (Pennak 1989).

The species composition of rotifers has been used as to characterize the degree of eutrophication in fresh waterbodies. Rotifers themselves are not known to have negative impacts on aquatic ecosystems. For example, Sládècek (1983) used the ratio of *Brachionus*:*Trichocera* as an indicator of saprobity (organic pollution manifested by biological oxygen demand). The characteristics of each genus we investigated as candidates for potential biota of concern are described below.

Asplancha. This is a widely dispersed genus found in the limnetic (open-water) zone. It is one of the most abundant open-water plankton groups (Pennak 1989). They are omnivores known to eat large algae and other rotifers.

Atrochus. Apparently widespread in distribution. There is little information regarding this genus.

Brachionus. A cosmopolitan genus that is most abundant in the littoral zone. It is common in the plankton as well, particularly in algal blooms and eutrophic areas. This genus serves as a indicator of eutrophism (Sládècek 1983). For some *Brachionus* species there is very little information availabe for, such as *Brachionus satanicus.*

Cephalodella. Several species are cosmopolitan in distribution. Generally benthic or attached to plants.

Colletheca. Most are sessile littoral species and many are predatory. *C. cornuta* is widely dispersed.

Colurella. A littoral genus with widespread distribution.

Filinia. *Filinia longiseta* is cosmopolitan and one of the most abundant open-water planktonic species. It is confined to alkaline waters. Is very abundant in lakes, but not rivers.

Hexarthra. Widely dispersed genus. Little information on *H. fennica*

Keratella. This is the most common rotifer genus. K. cochlearis is the most abundant Keratella species. Both *Keratella* species in Devils' Lake have cosmopolitan distribution (Dumont 1983).

Lecane. *Lecane bulla, L. inermis , L. lunaris, L. quadridenta*, are cosmopolitan in distribution. They are common in shallow, littoral zone and in limnetic zone of eutrophic rivers (Stemberger 1979 and Pennak 1989).

Lepadella. Widely dispersed in littoral zone. Species are very small.

Mytilina. *M. ventralis* is reported in littoral area and is widespread in distribution.

Notholca. A cold stenothermic genus with two species in the region. Both species are widely distributed.

Notommatta. Widely dispersed. Reported in littoral areas.

Philodina. A bdelloid rotifer capable of transforming its adult stage into a dormant cyst. Is widely dispersed in benthic habitats

Platyias. Found mostly in limnetic zone, in summer. Widely dispersed.

Ptygura. A sessile rotifer that is widely dispersed. At least 20 species are known (Pennak 1989).

Squatinella. Uncommon but widely dispersed.

Testudinella. Uncommon genus reported in littoral areas.

Trichocerca. Widely dispersed, found in Great Lakes, Red River and prairie potholes. Sládècek (1983) found that *Trichocera sp.* were most abundant in oligotrophic waters.

Species name: *Orconectes rusticus*
Common name: Rusty Crayfish.
Taxonomy: Phylum Arthropoda; Class Crustacea; Order Decapoda; Family Cambaridae;

Life History and Distribution.

Rusty crayfish are native to the Ohio River basin and southern U.S. They have larger, more robust claws than many other species and a dark, rusty spot on each side of the carapace. Rusty crayfish lay from 80 to 575 eggs that hatch in three to six weeks. The young stay with the female for several weeks, undergoing eight to ten molts before they are mature (1-2 years). Mature individuals can measure up to 4 inches long (Gunderson 2000).

Their original distribution was limited to the Ohio River basin, but they are now found in the upper Midwest (Michigan, Wisconsin and Minnesota, etc.), including the Great Lakes, as well as the northeast (New York, Rhode Island, etc.). It is not known to currently exist in the Devils Lake, Red River or Lake Winnipeg basins.

Rusty crayfish inhabit lakes, ponds, and streams. They require permanent lakes or streams with rocks, logs or other cover and suitable water quality all year (they don’t burrow). Bottom types may be variable as well as the velocity of streamflow.

It is not necessary to have a male and female crayfish transported to a lake to start a new population. One female carrying viable sperm may begin a new population. Their ability to invade new habitats is further enhanced by their aggressive nature toward other crayfish species. They compete successfully for food and shelter, driving native species out. Some habitats appear less favorable to this species, but whether this is true, and reasons why, remain unknown.

Size and Potential Detection

The rusty crayfish is not hard to detect as it is generally 1-4 inches in length. However, they have spread rapidly throughout the upper Midwest and their presence in many lakes may not have been detected yet. Identification is made easy because of the prominent rust-colored spots on their carapace, but spots do not occur on all individuals, so more obscure identifying characters must be found to confirm the identity of these individuals. Identification in these cases is not difficult for workers with a modicum of training.

Movement and Dispersal Mechanisms

Crayfish walk or climb about slowly using their side legs (pereiopods). They may also use their tail fan and abdomen to jump quickly when alarmed. They are capable swimmers over short distances near the bottom, and they may swim rapidly and somewhat continuously using the pereiopods (Pennak, 1989).

Rusty crayfish have been spread by humans from their original range. Their use as food and bait has facilitated their range expansion into the upper Midwest and northeast. Overland dispersal of crayfish by natural (non-human) means is thought to be rare.

Ecological Roles

Rusty crayfish are opportunistic feeders that may utilize aquatic plants, benthic invertebrates, detritus, fish eggs, and small fish. They have a variety of negative impacts on aquatic ecosystems where they are not native. Rusty crayfish displaces native crayfish because they are more aggressive. They cause destruction of aquatic plant beds which reduces available habitat for invertebrates, shelter for small fish, nesting areas for fish and shoreline erosion control. They may have negative effects on native fish populations for the above reasons and also because they compete with juvenile game fish for food (Gunderson 2000).

Species name: *Artemia salina, Artemia franciscana**
Common name: Brine Shrimp
Taxonomy: Phylum Arthropoda; Class Crustacea; Order Anostraca
* The globally described species "*Artemia salina*" is now considered to be a complex of closely related species or subspecies, the most common North American representative of which is *Artemia franciscana* (Drewes 2000).

Life History and Stages

Brine shrimp are dioecious, reproducing both parthenogenetically and bisexually. Factors determining the appearance of males (and subsequent bisexual reproduction) in the population are poorly understood. Females produce 1 to 6 clutches of 10 to 250 eggs each, at intervals of 2 to 6 days. The females die after final clutch production. Egg hatch appears to be determined by salinity and dissolved oxygen levels. Eggs produced in the spring are "summer eggs", which may hatch immediately. Those produced in fall are "winter eggs" or "resting eggs" that can endure extreme low temperatures and moisture until the following year. Post-hatch individuals pass through nauplius and metanauplius life stages, including probably 14 instars (characterized by ecdysis), including the final adult stage, although sexual maturity is reached in the twelfth instar (18 to 21 days after hatching). Spring development is particularly fast, with adult stages appearing shortly after ice melt. The normal post-hatch life span is approximately 4 months, with 2 or more generations produced each year in permanent waters.

Brine shrimp distribution is described as global, found on all continents except Antarctica.

They are found in brackish to saline inland waters, including man-made saline water bodies. They are not particularly sensitive to low oxygen (>1ppm DO appears to be the threshhold), but only the egg stage is tolerant of anoxia. They are euryhaline, preferring salinity above ~3% salt concentrations, though non-reproductive survival is possible in truly fresh water. Other than the above, habitat requirements are very plastic, although temperatures appear to trigger annual post-embryonic population growth and subsequent decline.

Brine shrimp are typically found in temporary waters and relatively depauperate saline waters. This limited distribution among habitats is probably because they are very susceptible to predation due to lack of defenses, rather than because of a physico-chemical habitat restriction.

Size and Detection Methods

Brine shrimp are classified as "macroinvertebrates" (>500 microns), so are readily observed with the naked eye and collected with standard invertebrate sampling nets.

Modes of Dispersal and Movement

All species in the order Anostraca are known for their ability to form dessication-resistant "resting eggs" which allows them to survive de-watered periods and disperse aerially over land by being passively wind-blown or carried by birds and insects. These eggs are unusually hardy, able to remain viable for years, regardless of environmental conditions. Resistant eggs collected from bird feces have been found to still be viable (Proctor 1964), so bird digestive tracts may serve as important overland conveyances for the species.

Function in Ecosystem

Trophic role: Omnivorous secondary consumers. Brine shrimp are suspension feeders, readily consuming a variety of micro- and meio- fauna and flora and particulate organic matter: algae, protozoa, bacteria, rotifers, suspended detritus. They, in turn, are fed upon by all predaceous invertebrates and fishes that are capable of consuming them. Their vulnerability to predators usually restricts them to relatively predator-free habitats.

Effects of new colonization: Unknown, but probably readily extirpated from new habitats if environmental conditions support a rich assembly of predators.

Taxon name: Conchostraca
Common name: Clam Shrimp
Taxonomy: Phylum Arthropoda; Class Crustacea;

Life History and Distribution

The life history and other biological characteristics of Conchostraca are very similar to those of their relatives, the Anostraca (described above). They do, however, bear striking anatomical differences. Conchostraca are crustaceans with a bivalved shell surrounding their body, hence the common name "clam shrimp". They are typically found in temporary waters, often with varying salinity, and are usually (but not always) notably absent from fish-bearing waters.

Size and Potential Detection

Clam shrimp adults are 2-16 mm long. They are readily captured with most typical macroinvertebrate sampling devices. Identification is not unusually difficult, but requires some expertise. The report of Conchostraca in the zooplankton of Devils Lake (Peterka 1986) is suspect, and could represent misidentified Ostracoda, which are similar in being bivalved, but are common in fish-bearing lakes.

Movement and Dispersal Mechanisms

Conchostraca are benthic, swimming along pond bottoms filter feeding on suspended material. As typical ephemeral pond inhabitants, clam shrimps produce dessication-resistant eggs. Like *A. salina* and other Anostraca, Conchostraca probably disperse most commonly by airborne transport of these eggs. Transport on larger animals has not been demonstrated, but should not be ruled out.

Ecological Roles

Like Anostraca, Conchostraca are filter-feeding omnivores. They are not known to be invasive or hazardous. In fact, because of their apparent susceptibility to predation, they may be considered a somewhat delicate group, only able to survive in habitats that are biologically safe, though physically and chemically harsh.

Taxon name: Order Cladocera
Common name: Water Fleas
Taxonomy: Phylum Arthropoda; Class Crustacea; Subclass Branchiopoda

Life History and Distribution.

Cladocera are small crustaceans that are one of the main components of the zooplankton throughout the world's fresh waters, and also form an important part of the littoral, pond and wetland meiofauna. PBOC cladocerans include species from several families, but all share very similar ecological functions, feeding modes ("grazers" except for a few predaceous species), movement habits, dispersal mechanisms and reproductive strategies. Species differ primarily in morphology, habitats within water bodies, and, to some extent, biogeography.

All Cladocera follow a similar progression of life stages: egg, juvenile, adolescent, and adult. As in Arthropoda in general, growth occurs when the animal sheds its exoskeleton (molts) and the body increases in size briefly until the new exoskeletal tissues harden. The entire post-hatch life of Cladocera consists of many such molting events, and each inter-molt stage is called an "instar". The juvenile stage consists of several instars, during which body size increases and the animal gradually metamorphoses into the adult form. The adolescent stage is a single instar during which the first clutch of eggs forms. When the adolescent molts, the eggs mature and the animal is considered a reproductively mature adult. Molting continues through the adult stage, with the number of instars varying widely by species, and a new clutch of eggs produced during each instar. Lifespan varies by species, temperature, food availability, and other environmental conditions. Under very favorable conditions, a single generation may require less than one month to pass from hatch to natural death, producing up to 25 clutches from 2 to 40 eggs each.

Reproduction can occur both sexually and asexually. Cladocera in particular are known for commonly reproducing parthenogenetically, often for many generations with no episodes of sexual reproduction. Eggs produced in this fashion develop from ova that contain diploid clones of the mother's genome. The eggs are carried in the mother's brood pouch and hatch into females unless a sexual generation of males and females is produced.

Males are only produced when environmental conditions change, particularly when the conditions become more adverse to species growth and survival. Induction of male production remains incompletely understood, but changes in several environmental conditions are responsible. Only some females produce males at a given time. Following the appearance of males in a population, some females begin producing sexual (haploid) eggs and proceed to mate with the males. This results in one or two fertilized, genetically varied eggs that are encased in a protective, environmentally resistant case called an ephippium. Ephippia are released from the female at their next molt and settle to the bottom, float, or are attached to stable substrates. They can endure extremes in temperature, water chemistry, and dessication. In many species ephippial eggs can remain viable through complete drying and other adverse conditions for several years.

When environmental conditions improve, ephippial eggs hatch, giving rise to a female population that will commence asexual reproduction until environmental conditions trigger a sexual episode again.

Most species are widespread in North America and commonly found in large and small lentic water bodies. Some are more locally distributed, or are widespread but rarely occur in large numbers. Despite widespread distribution, there may be significant morphological and genetic differences between groups of the same species that are separated by continents and other natural barriers (Frey 1987). The breadth of distribution and commonness of each species under consideration for this report are listed in Table 9.

Cladocera are almost exclusively freshwater organisms. Only a few species tolerate brackish conditions. They are not generally found in lotic waters because they cannot resist flow by swimming against it or attaching to substrata. They are commonly found in lentic waters of all sizes, including temporary waters, but they are most abundant in open-lake limnetic zones. Some species are also littoral, occurring within the vegetated shallows and in small ponds. Many species occur commonly in temporary waters, but it is unknown whether any species is strictly excluded from such habitats by an inability to withstand dry conditions.

Like most zooplankters, limnetic cladocera go through daily vertical migrations, rising to surface waters at night to feed and descending when light increases, presumable avoiding predation by visually feeding fishes. Many species exhibit cyclomorphosis, seasonal changes in body shape that are believed to confer predation resistance when predator densities change.

<u>Size and Potential Detection</u>

Most species' adult sizes fall in a range from 0.2 mm to 5 mm long, and are readily collected in standard plankton nets. Juveniles are considerably smaller, and are more likely to be missed by collectors. However, individuals of all life stages occur in populations simultaneously, so collection of juveniles is not necessary to for determining species composition of Cladocera assemblages. More important is the need to sample all habitats within a water body. Vegetation-associated and benthic species are often overlooked because most investigators working in these lake zones have used larger mesh sizes, focusing on macroinvertebrates, while "zooplankton" studies generally concentrate on limnetic zones. Many species in a lake or pond are never detected because investigators fail to collect samples from littoral habitats.

<u>Movement and Dispersal Mechanisms</u>

Water-borne dispersal is largely passive because cladocera are relatively weak swimmers. Most of their swimming effort is spent on daily vertical migrations or on very small-scale horizontal foraging movement. The main mode of dispersal through water occurs through water currents.

Cladocera can disperse overland in the ephippial egg stage. They may be "accidentally" carried by birds and mammals (Proctor 1964, Proctor and Malone 1965), or may be carried by wind (Brendonck and Riddoch 1998) when they occur in exposed and dried sediments at the edges of lakes or on the bottoms of temporary waters. The ease of wind-blown dispersal of ephippia may be an important reason for the cosmopolitan distribution of the majority of species.

Crustaceans (Cladocera and Copepoda) are also carried downstream as “drift” in rivers because of their limited swimming ability. Zooplankton carried as drift tends to drop out of the plankton as they move downstream from a source lake or reservoir (Akopian et al 1999, Sandlund 1982, and Ward 1975). Because of higher water velocities and shorter water residence times crustaceans are less abundant in rivers than they are in lakes and reservoirs such as Lake Winnipeg. In large or slow-moving rivers, planktonic species may form self-sustaining populations, since the water velocity is slower and residence time is much longer (Allan 1995).

Ecological Roles

Cladocera are grazers on suspended algae (except long filaments), protozoa, bacteria, and particulate organic matter. A small minority of species are predaceous on other zooplankton. They are a major food source for small fishes, including larvae and juveniles of large fish species, as well as a variety of predatory invertebrates. As such, they are a very important link in the food chain. They are a conduit of energy from primary producers to higher consumers, and are usually considered to be the most important group of primary consumers in pelagic systems.

Taxon name: Subclass Copepoda
Common name: Copepods
Taxonomy: Phylum Arthropoda; Class Crustacea

Life History and Distribution.

Copepods comprise a substantial component of the zooplankton and littoral and benthic meiofauna in all fresh waters. PBOC copepods include species from three suborders, Cyclopoida, Calanoida, and Harpacticoida, that differ somewhat in ecological niche, as discussed below. Calanoida are almost exclusively limnetic, Harpacticoida are benthic, and Cyclopoida occur in a variety of freshwater environments. Of the three, the Harpacticoida are by far the least studied. The collective features of the freshwater copepods are described below, but species-specific habitat and distribution information are listed in Table 11.

All PBOC Copepoda follow a similar progression of life stages: egg, nauplius, copepodite, and adult copepod. Most copepods reproduce sexually, although parthenogenetic reprouction has been observed in a few species. Females mate with males, sperm from the copulation is cached, and eggs are fertilized and carried by the female in paired external ovisacs containing 5 to 40 eggs each. Within a few days, the eggs hatch and the mother forms new ovisacs containing eggs fertilized from the sperm cache. Seven to 13 clutches may be fertilized by sperm from a single copulation. The first post-hatch stage is the nauplius, which goes through several molts, increasing appendage number in each instar (inter-molt forms). The next stage, the copepodid, more closely resembles the adult form and goes through several more molts. The final stage, and terminal instar, is the reproductively mature adult. The entire life span varies according to species and environmental conditions, and can last from 7 to about 180 days, although some species may live for up to 3 years. Copepods withstand adverse environmental conditions, including winter, by forming thick-walled resting eggs, or dormant juvenile stages.

Most species are cosmopolitan, or at least very widespread, though some species are more localized. Reasons for such geographic limitation are not known.

Freshwater copepods descended from marine relatives, and greater diversity is still apparent in the marine fauna. Nonetheless, most freshwater species are not found in marine or brackish environments. In general, they are commonly found in all freshwaters, in littoral and limnetic habitats and in permanent and temporary waters. Harpacticoida and, to some extent, Cyclopoida are important members of the interstitial and hyporheic meiofauna. Calanoida are mostly found in limnetic zones. Few copepods are found in areas with high flow rates.

Size and Potential Detection

Most species' adult sizes are from 0.3 to 3.2 mm long, and are readily collected in standard plankton nets. Juveniles are considerably smaller, and are more likely to be missed by collectors. However, individuals of all life stages occur in populations simultaneously, so collection of juveniles is not necessary to for determining species composition of Copepoda assemblages. More important is the need to sample all habitats within a water body. Vegetation-associated and benthic species are often overlooked because most investigators working in these lake zones have used larger mesh sizes, focusing on macroinvertebrates, while "zooplankton" studies generally concentrate on limnetic zones. Many species in a lake or pond are never detected because investigators fail to collect samples from littoral habitats, hence the lack of knowledge about the benthic Harpacticoida.

Movement and Dispersal Mechanisms

Water-borne dispersal is largely passive, although copepods display somewhat more directional swimming activity than some meiofauna. Dispersal within a water body occurs through both active and passive (water current) mechanisms.

Calanoid and harpacticoid copepods can disperse overland as resting eggs and encysted dormant juveniles blown by wind (Brendonck and Riddoch 1998) and carried by birds and mammals (Proctor 1964, Proctor and Malone 1965). The cyclopoid copepods are not known to produce such resistant stages, yet they are very widespread and commonly occur in temporary waters, so they must be able to endure harsh environmental conditions in some stage, most likely in the copepodid stage.

Planktonic crustaceans (Cladocera and Copepoda) are also carried downstream as “drift” in rivers because of their limited swimming ability. Zooplankton carried as drift tends to drop out of the plankton as they move downstream from a source lake or reservoir, especially the larger crustaceans (Akopian et al 1999, Sandlund 1982, and Ward 1975). Because of higher water velocities and shorter water residence times crustaceans are less abundant in rivers than they are in lakes and reservoirs such as Lake Winnipeg. In large or slow-moving rivers, planktonic species may form self-sustaining populations, since the water velocity is slower and residence time is much longer (Allan 1995).

Ecological Roles

Copepods are omnivorous, though their feeding habits differ somewhat by suborder. Harpacticoids are benthic, so their food is benthic organic matter, protozoa, and algae. Calanoids use a filter-feeding mechanism to collect suspended algae, organic matter, and protozoans, while cyclopoids have grabbing and biting appendages that are used to capture larger food: larger particulate organic matter, algae, and other animals, including their own species. Copepods are an important food source for small fishes, including larvae and juveniles of large fish species, as well as a variety of predatory invertebrates. As such, they are a very important link in the food chain. They are a conduit of energy from primary producers to higher consumers. They are also the intermediate hosts of several parasites of fish and amphibians.

Identification of Potential Species of Concern: Cladocera and Copepoda

The Crustacean species composition is fairly well described in Devils Lake, but there is a lack of data for Sheyenne and Red Rivers. There is however, a large amount of data on the zooplankton composition of Lake Winnipeg (and other areas of Canada), from reports by Bajkov (1934), Patalas (1971), Patalas (1981), Patalas and Salki (1992), and Stewart et al. (2000). For this reason, and because crustacean species are more likely to establish successfully in lakes, particular attention was given to differences in zooplankton composition between the two major lakes. The species listed in Table 12 were found to occur in Devils Lake but not Lake Winnipeg.

Species from Table 11 that were reported to be widely distributed in North America and/or cosmopolitan (reported in Europe or Asia as well as North America) were not considered potential threats to downstream aquatic ecosystems. They were eliminated as PBOC. The species that were not widespread elsewhere, but occurred in Devils lake were examined in more detail to determine if they were PBOC. Many of the PBOC Crustacea were planktonic species favoring saline environments (*Daphnia similis and Diaptomus nevadensis*). Also the harpacticoid genus, *Cletocamptus* and *Laophonte* were considered in more detail, because there is almost no information available regarding either of these groups.

None of the crustacean species native to Devils Lake are known to have negative impacts on aquatic ecosystems. It is unclear, however, what effect introduced Crustacea species would have on the lotic environment of the Sheyenne and Red Rivers. The most likely impact of introducing new zooplankton species may be alteration of population dynamics of the existing zooplankton and/or phytoplankton communities, particularly in Lake Ashtabula and Lake Winnipeg. Species that have radically different morphology or life history than extant species are the most likely to create problems.

For example, several Eurasian zooplankton have invaded North American waters, including *B. cederstroemi* (spiny water flea) in the Great Lakes, *Daphnia lumholtzi* in the Illinois River basin (Stoeckel and Charlebois 1999), and *Bosmina (Eubosmina) coregoni coregoni* which invaded N. America from Eurasia (Lieder 1991). *B. coregoni* is now present in Lake Winnipeg (A. Salki, personal communication). *Bythotrephes* has a large spine that deters grazing giving it a competitive advantage over native crustaceans. Spiny water flea is thought to have caused a reduction in small native cladoceran species in parts of Lake Michigan. However, none of the zooplankton observed in Devils Lake are exotic species, nor radically different from species that exist in downstream ecosystems. Furthermore, since Devils Lake, the RRB and Lake Winnipeg have been connected several times during the Holocene period it likely that zooplankton species have already had the opportunity to disperse into the RRB several times.

Potential Cladocera and Copepoda of concern

The following crustacea were reported from Devils Lake, but not from the Sheyenne River, Red River, or Lake Winnipeg.

***Daphnia similis* (Cladocera) and *Diaptomus nevadensis* (Copepoda):**

These species are distributed widely throughout Eurasia. Hebert and Finston (1992) report *D. similis* throughout the Nearctic Range. In North America, it is found primarily in the western United States and Canada. Hebert and Finston (1992) collected samples of the species in British Columbia, California, Colorado, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Saskatchewan, Texas, Utah, and Washington in temporary, saline, or alkaline ponds. It prefers higher salinity than many daphnids. Its distribution is nearly similar to that of *Diaptomus nevadensis* (Patalas, Patalas, and Salki 1994).

In North America, *Diaptomus nevadensis* is found primarily in the western United States and Canada in temporary, saline, or alkaline ponds. It has been reported in California, Nevada, Washington, North Dakota and western Canada. *D. nevadensis* is a carnivorous species. Leucke (1986) found that *D. nevadensis* was eliminated from an alkaline lake in Washington by the introduction of *Chaoborus flavicans*, suggesting that *D. nevadensis* may not be a highly competitive species.

These are widespread species, and not considered exotics in the region. However, the Red River and Lake Winnipeg are at the eastern edge of their present range, so a spread into the Red River system and Lake Winnipeg would extend their geographic range Their presence in Devils Lake suggests that they have had access to the RRB historically, and their habitat preferences suggest that they have not found RRB or Lake Winnipeg waters suitable.

Harpacticoid copepods:

While most copepods are planktonic, the harpacticoids are benthic. There has been little research done on this taxonomic group and thus much is unknown about their distribution and ecology. Little information specifically addressing *Cletocampus albuquerquensis* is available. It was found in the Cottonwood Lakes area of North Dakota, very close to the Sheyenne River (LaBaugh and Swanson 1988), so it has probably had historic access to the RRB and found it unsuitable. The genus *Laophonte* is widely distributed. One species of *Laophonte* was reported in the Lake Winnipeg Basin by Bakjov (1934). The harpacticoids are not known to have any characteristics that would make them a threat to downstream ecosystems. Because they can also live in wet soil and interstitial spaces, they are capable of dispersing across areas without surface water connections.

Taxon name: *Cypris pellucida*
Common name: seed shrimps
Taxonomy: Phylum Crustacea; Class Ostracoda;

Life history and distribution.

Ostracoda have been much less studied than other microcrustaceans. They occur in substrates of both lentic and lotic environments as well as marine. The name seed shrimp comes from the ostracods' hard bivalve shell or carapace. Ostracods produce eggs that go dormant during unfavorable conditions. Viable eggs may be able to survive for up to 20 years in the desiccated state (Pennak 1989). Most genera and some species have cosmopolitan or Holarctic distribution. They are thought to be dispersed in much the same way as cladocerans and copepods. However the scant amount of research and data leaves many blanks concerning actual distributions.

Size and Potential Detection

American fresh-water ostracods are generally between 1 and 3 mm long (Pennak 1989). Ostracods are generally collected from masses of debris from streams or lakes. Difficulties in sorting ostracods from mud has contributed to the lack of research on this group. Their size of 1 to 3 mm is easily visible in a dissecting microscope.

Movement and Dispersal Mechanisms

Ostracods can move about on the substrate by means of beating movements of their antennae. Some species can leave the bottom and swim about actively. They are moved about through passive distribution in water currents. Wind and animal dispersal likely provide overland dispersal as with cladocerans and copepods. Ostracods are even more widely dispersed than these other groups because of the extreme toughness of their resting eggs.

Ecological Roles

Most ostracods are omnivorous suspension and deposit feeders, preferentially filtering fine organic particles. Some ostracods act as commensals on the gills and articular membranes of crayfishes. They are preyed upon by a wide range of fish, invertebrates, and birds.

Taxon name: *Gyratrix hermaphroditus*
Common name: free-living flatworms
Taxonomy: Phylum Platyhelminthes; Class Turbellaria;

Life history and distribution

Most fresh-water flatworms are elongate and dorsoventrally flat. In many species the anterior end is specialized enough to resemble a head. The mouth tends to be on the ventral side and is used to feed on small living invertebrates and possibly some detritus.

Most flatworms have photosensitive eyespots, allowing them to seek shaded shelters. They reproduce both asexually (by fission) and sexually. All American fresh-water turbellarians are hermaphroditic. Sexual reproduction occurs when, two organisms exchange sperm whereby eggs may be fertilized in both flatworms. Asexual reproduction via fission can enable one organism to reproduce itself for years and years. Some species of flatworms can also regenerate after being cut in two.

Turbellaria are typically found in vegetated, oxygenated waters feeding on live and dead animals. *G. hermaphroditus* is found in both fresh and brackish waters, and is widespread in Europe as well as the United States (Higley 1918). Little is known about the geographic distribution of flatworm species, particularly microscopic turbellarians and the turbellaria found west of the Mississippi River. East of the Mississippi much more information is available. Many species are widely distributed. The cyst stages, winter eggs and even possibly cocoons, enable widespread dispersal of flatworms via wind, water and larger animals.

Size and Potential Detection

The order Tricladida contains species that are usually 5 to 30mm long, while the other flatworm orders are microscopic, usually between 300 and 1200 ìm (Pennak 1989). The larger flatworms are easily detected. They are often collected by “baiting’ glass jars with perforated lids.

Movement and Dispersal Mechanisms

Flatworms move by using their cilia as well as faint waves of muscular contractions that pass longitudinally down the body. They generally cannot swim, but require a substrate to move on. When conditions are unfavorable, flatworms can lie inactive for days at a time. Overland dispersal is thought to be accomplished mainly during cyst and winter egg stages.

Ecological Roles

Flatworms occur in springs, brooks, ditches, marshes, pools, lakes and other small water bodies. In general, specimens from running waters attain greater size than those found in standing waters. Microscopic turbellarians are thought to be abundant on the bottom and in the interstitial waters of streams and springs. They are generally not an important food source for other animals. Flatworms can carry some internal parasites including ciliates, gregarines, and larval nematodes (Pennak 1989).

Taxon name: *Chaetonotus maximus*
Common name: gastrotrichs
Taxonomy: Phylum Gastrotricha;

Life History and Distribution

Gastrotrichs are microscopic, aquatic organisms that are similar in some respects to rotifers. They have some phylogenetic relationship to the Nematoda, Kinoryhncha, and Turbellaria. There is less known about gastrotrichs than most phyla because very little research has been focused on this group.

Gastrotrichs are are seemingly obscure, but they are found in freshwater and marine habitats everywhere. They are typical of marshes, shallow ponds, and the shallow littoral zone of lakes where there is detritus and decaying material to feed on. Most species are closely associated with a substrate, though a few species can freely swim. Many gastrotrichs are found in the capillary water of sandy beaches within a meter or two from the water's edge. They are thought to be able to tolerate minimal periods of anaerobiosis. *C. maximus* is classified as a "brackish, limnic" species (White 2001).

Reproduction is primarily through parthenogenesis (asexual reproduction), although some form of sexual reproduction may occur. Fresh-water species are all parthenogenetic females, however. A gastrotrich produces only one to five eggs during its lifetime, most of which hatch within 12-70 hours after being deposited. They produce another form of egg (opsiblastic) that is slightly larger and may withstand desiccation, freezing, and high temperatures.

There has been almost no intensive, systematic collection of gastrotrichs. Most records were incidentally taken as part of other data collection. Most fresh-water genera appear to be cosmopolitan and occur the world over in suitable habitats (Pennak, 1989).

Size and Potential Detection

Most species are 100 to 300 μm in length, although a few are as small as 70 μm and some get up to 600 μm. They are similar in size to rotifers. They could be caught in standard planktonic sampling nets (Pennak, 1989). However, since most occur on the top of a substrate, sampling would be most fruitful in littoral areas, shallow ponds, and/or the wet zone of beaches.

Movement and Dispersal Mechanisms

Gastrotrichs move by beating their ventral cilia against a substrate, producing a smooth, gliding type of motion that can be quite rapid. Most gastrotrichs can leave the substrate and swim about in the water with the ventral and head cilia, but seldom go far above the substrate.

Presumably, this phylum is readily dispersed, because of the cosmopolitan distribution of some species. *C. maximus* is classified as "cosmopolitan" by White (2001). The desiccant-resistant opsiblastic eggs may facilitate overland dispersal in a way similar to rotifers, nematodes and other invertebrates. The drought-resistant eggs are likely easily carried by wind in dried-out soil and transported by animals.

Ecological Roles

Very little is known about gastrotrichs, particularly their ecology. Most research has centered on taxonomy and/or physiology. They are known to play the role of detritivore, facilitating the transport of energy from decomposed material to higher trophic levels. Gastrotrichs may play an important role in the ecological interaction of some substrates, such as in the capillary zone of sandy beaches.

Taxon name: Phylum Nematoda
Common name: Roundworms

Life history and distribution

Roundworms are small worms that are ubiquitous in sand, mud, debris, vegetation, pond, lake or rivers. Nematodes are in nearly constant movement, with thrashing serpentine movements that produce little locomotion in open water. Nematodes are abundant on the substrates of freshwaters. There has been a great deal of research on parasitic and predatory species, which are of extreme importance to the health, and economy of people. There is very little scientific information available on the 1500+ free-living species that occur in freshwaters around the world (Pennak 1989). Many free-living nematodes, including all the PBOC taxa in this study, are not obligate aquatic animals, but can live equally successfully in moist soil habitats (Warwick 1984).

There is little information concerning nematode distribution. Based on available records, it appears that most aquatic genera are cosmopolitan and worldwide. They are one of the most adaptable of all phyla and are able to thrive in a wide variety of habitats and ecological conditions.

Size and Potential Detection

They range from microscopic (µm) in length to millimeters (Pennak 1989). Nematodes have generally been avoided by aquatic biologists as research subjects because they generally occur in bottom mud and fine organic debris from which it is difficult to extract them. It also difficult to identify many roundworms to species or even the genus level. Fine structure of mouthparts and other very small structures are usually used in identification. Expert knowlede and good quality microscopic equipment are needed for this work.

Movement and Dispersal Mechanisms

Most nematodes move by a thrashing motion that propels them along the substrate. Only a few are capable of free-swimming. A few species can also move along the substrate like an inchworm. The eggs of soil and parasitic nematodes are highly resistant to desiccation (up to 10-20 years) and are readily transported by animals and wind. Less is known about the encystment and desiccation of aquatic nematodes. It is generally thought that most nematodes are readily dispersed overland due to the diversity of locations where they occur and their ability to form desiccation-resistant cysts.

Ecological Roles

Some nematodes are parasitic but most are free-living species that occupy wet soils and the substrates of water bodies in great abundance. Nematode species fill all trophic functions: predator, grazer, detritivore, etc. They are important mechanically for stirring and mixing soils in much the same way earthworms are in terrestrial soils. Aquatic micro-nematodes are very much tied to the substrate that they occupy. They are important members of the meiobenthos, usually occupying the top 5 cm of substrate.

3.5.1.4 Biology of PBOC: Fishes: Striped Bass

Scientific name: *Morone saxatilis* (Family Percichthyidae)
Common name: Striped Bass

Life History and Distribution

The native range of striped bass encompasses the North American Atlantic coast from the St. Lawrence River in Canada south to the St. Johns River in northern Florida, and disjunctly in the Gulf of Mexico from Louisiana to the Suwanee River, Florida (Lee et al. 1980). Striped bass were introduced to the Pacific coast by stocking 135 yearling striped bass in the Sacramento River in 1879, and 300 more in 1882 (Setzler et al. 1980). This stocking established a population that subsequently expanded throughout the Pacific coast from the Columbia River to Ensenada, Mexico (Setzler et al. 1980, Hassler 1988).

Striped bass have been widely introduced into freshwater habitats throughout the United States with the exception of the northeast, and the states of Idaho, Montana, Wyoming and South Dakota (Fuller et al. 1999). Stocked striped bass have established self-sustaining populations in a few freshwater systems, including the Kerr Reservoir in Virginia and North Carolina, Keystone Reservoir in Oklahoma, the Colorado River, and Lake of the Ozarks in Missouri (Setzler et al. 1980, Crance 1984). In addition, a naturally reproducing population was created in Santee-Cooper Reservoir in South Carolina when striped bass were trapped by construction of the Pinopolis Dam (Setzler et al. 1980).

Striped bass are currently sustained by annual stocking in many North American lakes (Fuller et al. 1999). However, most *Morone sp.* stocking programs rely on striped bass hybrids. Of the available hybrids, crosses of striped bass females with white bass (*Morone chrysops*) males have been the most successful in terms of growth and sport harvests, although the reverse cross is sometimes cultured and stocked (Fuller et al. 1999). Etnier and Starnes (1993) report that these striped bass (SB) x white bass (WB) hybrids occur naturally in Arkansas. Although these hybrids are not sterile, no successful reproduction between *Morone sp.* hybrids in natural habitats has been reported (Bonn et al. 1979, as cited in Setzler et al. 1980). The SB male x WB female hybrid has been reported to backcross to the parental species in the Ohio River (Fuller et al. 1999). Although white bass are relatively abundant in Devils Lake, and striped bass appear to be present at very low levels, no hybridization is believed to have occurred in Devils Lake, based on electrophoretic analyses of white bass (Steinwand et al. 1996). Fish culturists have also hybridized striped bass with white perch (*Morone americana*) and yellow bass (*Morone mississippiensis*), and both types of hybrids are sometimes stocked to support recreational fisheries (Fuller et al. 1999).

There is an extensive literature on the life history and habitat requirements of striped bass, particularly as it relates to spawning, early life history, and fish culture practices. The following summary of life history and habitats focuses on freshwater populations and life stages. In freshwater, males generally mature at 2 years while females generally mature at 4-6 years (Crance 1984). Striped bass require riverine habitat for spawning and lacustrine habitat for foraging and growth. Striped bass spawn in the spring, typically in large rivers at locations with moderate to high water velocity that is necessary to prevent the eggs and fry from settling on bottom (Setzler et al. 1980, Crance 1984). According to the review by Crance (1984), suitable spawning locations may be found where the river enters the lake or reservoir (e.g. Lake Powell on the Colorado River), or many miles upstream – for example, 50-60 miles upstream of Santee-Cooper Reservoir, 43-93 miles upstream of Keystone Reservoir, and 30-40 miles upstream of Kerr Reservoir. Spawning locations may have a variety of substrates ranging from coarse sand to boulders/rubble (Crance 1984). Peak spawning activity occurs at water temperatures from 16.7 to 19.4 °C (Crance 1984). Incubation requires about two days, depending on water temperature (Crance 1984). Fry have generally absorbed the yolk sac by about 5-10 days after hatching (Setzler et al. 1980). Developing fry can tolerate increasing salinity or dissolved solids – they can tolerate full sea water salinity by about one month after hatching (Setzler et al. 1984). By about one month post-hatch, striped bass typically have entered lacustrine habitats where they favor shallow areas with little current, and little or no vegetation (Crance 1984). As water temperatures increase and the fry grow to juveniles, they move to deeper water and form schools.

Water temperature and dissolved oxygen concentration are the principal environmental variables that determine lacustrine habitat suitability for juvenile and adult striped bass (Crance 1984). During the growing season, striped bass are generally found below the thermocline and avoid warmer surface waters. The preferred temperature range is about 18.5 to 25 °C (Crance 1984, Coutant 1987), although temperatures vary by region and older striped bass prefer lower water temperatures (Crance 1984). The upper lethal temperature is about 34.4 to 35 °C (Crance 1984) although summer temperatures of 27-28°C for a month or more result in mortality (Zale et al. 1990). Laboratory and in situ experiments indicate that dissolved oxygen must be at least 5.0 mg/l for long term survival, although lower levels may be tolerated for short periods (Crance 1984). Long periods of stratification in productive systems (i.e., mesotrophic to eutrophic) may produce unsuitable environmental conditions due to high temperatures in the epilimnion and low dissolved oxygen in the hypolimnion (Crance 1984, Zale et al. 1990). This “squeezes” the area of suitable habitat and causes striped bass to remain near the thermocline or seek cool water refuges (e.g., tributaries). These conditions may make striped bass more vulnerable to parasites, disease, toxic effects, or angling pressure, and can reduce foraging opportunities and growth (Crance 1984, Coutant 1978). Chronic recurrence of these conditions is associated with the loss of striped bass from lakes and reservoirs (Crance 1984).

Potential Detection

Striped bass in Devils Lake may be very scarce. This species was introduced to Devils Lake in 1977, when approximately 13,000 fingerlings were stocked (Steinwand et al. 1996). An estimated 30,000 hours of netting effort have been spent during spawning seasons on Devils Lake from 1977 through 1991. These efforts have resulted in the capture of only one striped bass (Steinwand et al. 1996). Three additional striped bass have been submitted by anglers for “whopper club” status, the most recent being June 1993 (Steinwand et al. 1996). These data indicate that the Devils Lake striped population is very small.

The population of striped bass in Devils Lake may consist of a few adult fish remaining from the original stocking in 1977. Reviews by Setzler et al. (1980) and Crance (1984) report specimens of striped bass that were in excess of 30 years old, with historic accounts of much larger fish that were presumably even older. Any survivors from the original Devils Lake stocking would now be 24 years old, well within reported age limits. Assuming there has been no natural reproduction, then only the occasional large adult striped bass would be expected in the future. These fish would be very large and easy to detect. However, they would be very uncommon.

<u>Mechanisms for Movement</u>

There are no indications that Devils Lake striped bass have successfully reproduced or hybridized with white bass (Steinwand et al. 1996). Most of the water bodies where striped bass have been introduced do not support reproduction and the populations must be maintained by stocking (Fuller et al. 1999). It appears that Devils Lake falls into this category. Thus, it is likely that the only striped bass present in Devils Lake are adults from the original stocking in 1977. Adult striped bass are mobile predators that may cover long distances while foraging. However, they are generally restricted to cool hypolimnetic waters (Crance 1984). Thus, adult dispersal may be more likely during spring or fall when water temperatures are cooler and more homogenous. Some records of the presence of striped bass in freshwater involved downstream dispersal far from original stocking locations, even over intervening dams or through hydroelectric turbines (Fuller et al. 1999). Thus, the most likely mechanism for movement and dispersal from Devils Lake is spring or fall emigration through the outlet works.

<u>Ecological Niche</u>

Striped bass in lacustrine environments are pelagic predators feeding at the top of the food chain (Axon and Whitehurst 1985). Adult striped bass are generally piscivorous although they may also consume insects and crustaceans (Crance 1984, Mathews et al. 1988). They are associated with the depletion of clupeids in some southeastern lakes (Bailey 1975, as cited in Fuller et al. 1999). Gizzard and threadfin shad are favored prey items in lacustrine environments (Crance 1984, Mathews et al. 1988), however, neither species is present in Devils Lake.

<u>3.5.1.5 Biology of PBOC: Fishes: Minnesota Prohibited_Species</u>

The status and distribution of Minnesota Prohibited and Exotic Fish Species are summarized below. The summaries draw upon information contained in Lee et al. (1980), Scott and Crossman (1998), Fuller et al. (1999), the USGS Nonindigenous Aquatic Species web site (http://nas.er.usgs.gov), and other sources, as noted.

Scientific name: *Hypophthalmichthys nobilis* Richardson
Common name: bighead carp

This exotic species is native to southern and central China. Since 1972, bighead carp have been illegally stocked and have escaped from aquaculture facilities. The species occurs in the Ohio and Missouri Rivers and other tributaries of the Mississippi southward from Iowa/Illinois. There is evidence of reproduction in the lower Mississippi and Missouri rivers in the states of Illinois and Missouri. It has been reported, but is not known to reproduce, in Alabama, Arkansas, California, Colorado, Florida, Indiana, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Ohio, Oklahoma, Tennessee, Texas and West Virginia.

This species is not known to be present in Devils Lake and has not been reported from North Dakota or Minnesota, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific Name: *Mylopharyngodon piceus* (Richardson) Peters
Common Name: black carp

This species originated in Eastern Asia. An estimated 30 black carp escaped from an aquaculture facility into the Osage River, tributary to the Missouri River, in 1994 when ponds were flooded by high flows. These fish may have been sterile triploids. None have been recovered from the Osage or Missouri Rivers.

This species is not known to be present in Devils Lake and has not been reported from North Dakota or Minnesota, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Ctenopharyngodon idella* Valenciennes
Common name: grass carp

This species is native to Eastern Asia. It has a widespread distribution in North America from historic and current stocking as a biological control measure for excessive aquatic vegetation. It has been documented in every state except Montana, Maine, Rhode Island and Vermont. Current releases in most states are restricted to sterile triploids. However, diploid (i.e., fertile) fish are likely released illegally. Reproducing populations have been documented in the middle and lower Mississippi River, including the major tributaries (Ohio and Missouri Rivers). Grass carp were stocked in Spiritwood Lake, North Dakota (Missouri River drainage) decades ago, and a small population persists there (T. Steinwand, pers. comm.).

This species has been found in the past in the Sheyenne River in North Dakota (Lee et al. 1980 et seq.) and at locations in Minnesota. However, it is not known to reproduce in these locations and neither Owen et al. (1981), nor Peterka et al. (1996) listed grass carp among Sheyenne River fishes. Grass carp are not known to be currently present, nor have they ever been documented, in Devils Lake. It is unlikely that water diversion from Devils Lake will have any effect on the few, if any, grass carp that may be present in the Sheyenne or Red Rivers.

Scientific name: *Neogobius melanostomus*
Common name: round goby

This Eurasian fish was apparently introduced into the Great Lakes via the release of ballast water from freighters. It was initially reported from Lake St. Clair and has since been found in additional locations in the Great Lakes. The species may be undergoing a rapid population and range expansion in the Great Lakes basin. Only two specimens have been found in Lake Superior, including a single specimen from Duluth harbor.

This species is not known to be present in Devils Lake and has not been reported from North Dakota or inland Minnesota waters, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Scardinius erythrophthalmus* Linnaeus
Common name: rudd

This species is native to freshwater habitats in Western Europe. It was initially brought to North America either in the late 1800's or early 1900's. Over time, the use and culture for bait purposes resulted in widespread distribution in the central and northeastern United States. Reproductive populations have been reported from Maine (since 1973), Massachusetts, Nebraska, New York (since early 1900's), and three water bodies in South Dakota (Pactola Reservoir, Sheraton Lake and Newall Lake). A breeding population in Kansas appears to have been successfully eradicated. Rudd has never been reported from Minnesota or North Dakota.

This species is not known to be present in Devils Lake and has not been reported from North Dakota or Minnesota, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific Name: *Gymnocephalus cernuus* Linnaeus
Common Name: ruffe

This Northern European fish was apparently introduced into western Lake Superior as early as 1982-83 via the release of ballast water from freighters. Over the 1990's, ruffe spread eastward to the upper peninsula of Michigan. In 1995, the species was first found in Lake Huron. It has not expanded to inland areas of Minnesota.

This species is not known to be present in Devils Lake and has not been reported from North Dakota or inland Minnesota, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Petromyzon marinus* Linnaeus
Common name: sea lamprey

Sea lamprey are an anadromous species that is native to the Atlantic coast of North America. Controversy exists as to whether this species is also native to Lake Ontario where they have been known since the 1830's. Sea lamprey expanded their range westward through the Great Lakes via ship canals and locks beginning with Lake Ontario in the 1830's and reaching Lake Superior by 1947. Sea lamprey utilize freshwater tributaries for spawning and rearing. Various control measures have been used in some Great Lakes tributaries to preclude spawning access or eradicate juveniles.

This species is not known to be present in Devils Lake and has not been reported from North Dakota, the RRB or the upper Mississippi River, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Hypophthalmichthys molitrix* Valenciennes
Common name: silver carp

This native distribution of this species includes much of Eastern Asia. It was imported and released for phytoplankton control in the early 1970's. By the mid 1970's it was being raised by numerous state, federal, and private hatcheries. It has been intentionally or accidentally released in the following states; Alabama, Arizona, Arkansas, Colorado, Florida, Illinois, Indiana, Kansas, Kentucky, Louisiana, Missouri and Tennessee. It is present in the Ohio and Missouri Rivers and other tributaries of the Mississippi southward from Illinois and Missouri.

This species is not known to be present in Devils Lake and has not been reported from North Dakota or Minnesota, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Morone americana* Gmelin
Common name: white perch

White perch are native to the Atlantic slope drainages of North America from the St. Lawrence River to South Carolina. The species spread into the Great Lakes via ship canals. Dates of first reports in the Great Lakes are as follows; Lake Erie in 1953, Lake St. Clair in 1977, Lake Huron in 1987, Lake Michigan in 1988, and Lake Superior in 1986. The Lake Superior population is restricted to Duluth Harbor, the warmest part of Lake Superior. Since it pre-dates the Lake Huron and Lake Michigan records, it likely represents a separate introduction. White perch were accidentally released into the Missouri River in Nebraska and have spread downstream. In summary, introduced populations of white perch are established in all five Great Lakes, the surrounding states, as well as in Kentucky, Massachusetts, Missouri, Nebraska, New Hampshire, and Vermont.

This species is not known to be present in Devils Lake and has not been reported from North Dakota or inland Minnesota, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Stizostedion lucioperca* Linnaeus
Taxonomy: Class Osteichthyes; Family Percidae
Common name: zander

The native range of this species is from continental Europe to western Siberia. It was illegally introduced into several ponds in New York in the 1970's, but may no longer be present in New York. The species was introduced by the North Dakota Game and Fish Department into Spiritwood Lake in 1989 in order to evaluate the potential of the species as a game fish. This waterbody was chosen since it has no outlet. Only one survivor was recovered during a subsequent netting survey and since then it was believed these fish had not survived until a fisherman recently caught a single two-year-old individual, suggesting that at least one successful mating occurred among the original stock (USGS 2000).

Little is known about the zander's life history in North America, but it is assumed to be similar to that of the N. American walleye. They are known to feed heavily upon small prey. One concern is that the species would cause a collapse in the resident prey fish stocks. Zander have never been stocked in Devils Lake, but if it is "accidentally" transplanted to areas such as Lake Winnipeg or Devils Lake, it would probably compete with the native walleye. The results of such an interaction are not predictable, but zander prefer eutrophic, turbid, well oxygenated water with a low mean depth, and in rivers they prefer slow-flowing rather than turbulent water (USGS 2000). These preferences differ from typical walleye habitat, so the two species would be likely to partition habitat between them, should they happen to co-occur. This suggests that zander could be more likely to compete with less-related species, such as centrarchids and esocids.

Zander have never been stocked in Devils Lake, nor in any downstream waters. Therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species unless it is subsequently introduced into the lake.

3.5.1.6 Biology of PBOC: Fishes: Minnesota Regulated_Species

The status and distribution of Minnesota Prohibited and Exotic Fish Species are summarized below. The summaries draw upon information contained in Lee et al. (1980 et seq.), Scott and Crossman (1998), Fuller et al. (1999), the USGS Nonindigenous Aquatic Species web site (http://nas.er.usgs.gov), and other sources, as noted.

Scientific name: *Alosa pseudoharengus* Wilson
Common name: alewife

Alewife are an anadromous species that is native to the Atlantic coast of North America from Labrador to South Carolina. There is some controversy as to whether this species is native to Lake Ontario. The first record in Lake Ontario is from 1873. From there it has spread to the other Great Lakes with the following dates of first reports; Lake Erie in 1931, Lake Huron in 1933, Lake Michigan in 1949, and Lake Superior in 1954. It is often very abundant in Lakes Michigan, Erie, and Ontario – periodic large-scale die-offs cause nuisance and water quality problems in these lakes. Alewife are much less abundant in Lakes Huron and Superior. In addition to the Great Lakes, freshwater populations have been introduced in the following states; Colorado, Georgia, Kentucky, Maine, Massachusetts, Nebraska, New Hampshire, Pennsylvania, Tennessee, Vermont, Virginia, West Virginia, and Wisconsin.

This species is not present in Devils Lake and has not been reported from North Dakota or inland Minnesota, therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Cyprinus carpio* Linnaeus
Common name: common carp, koi

Common carp are native to Eurasia, where they have been distributed widely and hybridize with closely related species. They were first imported to North America as early as 1831 as a food fish and were well established by the late 19th century. They have been stocked, or expanded their range naturally, to much of North America. Self-sustaining populations are present in every state except Alaska and Maine. Common carp are present in the Canadian provinces of British Columbia, Manitoba, Ontario, Quebec, and Saskatchewan. Many waters in Manitoba contain common carp, and after 1938 carp were caught in commercial fisheries in southern Lake Winnipeg. Introductions in Alberta may not have resulted in populations becoming established.

Common carp are not present in Devils Lake. Common carp are established in downstream waters of the Sheyenne River, the Red River of the North, and Lake Winnipeg. Therefore, water diversion from Devils Lake will have no effect on the future distribution and abundance of this species.

Scientific name: *Carassius auratus* Linnaeus
Common name: goldfish

Goldfish are a Eurasian fish of complex taxonomy due to a long history of captive breeding, widespread distribution by man, and hybridization with closely related species. In North America, the species was introduced as early as the 17th century. Widespread distribution in the 19th century has resulted in the species becoming established in every state except Alaska.

Goldfish have been illegally released in Canadian Provinces of Alberta, British Columbia, Manitoba, Ontario, Quebec, Saskatchewan, and probably the maritime provinces. Goldfish are established in Ontario and British Columbia.

Goldfish are not present in Devils Lake. Goldfish were reported in the Sheyenne River in 1966 (Owen et al. 1981) but not in subsequent fish surveys. Goldfish are present in other areas in North Dakota as well as locations in Minnesota. Therefore, it is unlikely that water diversion from Devils Lake will have an effect on the future distribution and abundance of this species.

Scientific name: *Osmerus mordax* Mitchell
Common name: rainbow smelt

Historically, several species and/or sub-species of *Osmerus* have been recognized in North America (see Scott and Crossman 1998 for a discussion of taxonomy). However, current taxonomy recognizes only *Osmerus mordax* for the Arctic, Pacific, Atlantic, and freshwater dwarf forms of this species (Robbins et al. 1991). The native range of this species includes anadromous runs in the Atlantic coastal drainages from Newfoundland to the Delaware River, and landlocked populations in many lakes in New England, the maritime provinces of Canada, Quebec, and eastern Ontario. The Arctic and Pacific portions of the range extend from the Northwest Territory to Vancouver Island. The species has been introduced into many North American lakes in the United States and Canada. Great Lakes introductions began when rainbow smelt were stocked in Crystal Lake in Michigan in 1912. From there, they moved downstream and colonized the Great Lakes. The dates of first observations in the Great Lakes are as follows; Lake Michigan in 1923, Lake Superior in 1923, Lake Huron in 1925, Lake Ontario in 1929, and Lake Erie in 1935. The earlier date for Lake Ontario, relative to Lake Erie, is believed to be a result of a separate introduction.

Introductions in Ontario are primarily the result of bait bucket transfers and other illegal stockings. Rainbow smelt do not appear to be present in any portions of the Hudson Bay drainage. In the United States, the species has been stocked in many lakes in eastern, central, and northern Rocky Mountain states. Introduction into Lake Sakakawea in North Dakota is believed to have led to a downstream distribution into the Missouri and Mississippi Rivers, although the downstream populations may be maintained by drift from upstream reservoirs on the Missouri River. In addition to the Great Lakes and Missouri/Mississippi River introductions, the following states have introduced rainbow smelt in freshwater habitats; Colorado, Connecticut, Georgia (since extirpated), Idaho, Maine, Maryland, Massachusetts, Montana, New Hampshire, New York, North Carolina, Pennsylvania, Tennessee, Vermont, and Virginia.

Rainbow smelt are not present in Devils Lake, the Red River of the North, nor it's tributaries. Therefore, water diversion from Devils Lake will not have an effect on the future distribution and abundance of this species.

Scientific name: *Tilapia, Oreochromis, Sarotherodon* spp.
Common name: tilapia

The vernacular name "tilapia" refers to numerous related cichlid species that are native to tropical and/or subtropical Africa. Tilapiine cichlids are a somewhat poorly defined taxonomic assemblage that includes eight or more genera and well over a hundred described species, to date. Four species in the genus *Tilapia* are present in North America; *T. mariae, T. rendalli, T.*

sparrmani, and *T. zilli*. Five species in the genus *Oreochromis* are present in North America; *O. aureus, O. macrochir, O. mossambicus, O. niloticus,* and *O. urolepis*. The only species of *Sarotherodon* known to occur in North America is *S. melanotheron*. In addition to these ten species, additional species may be present, and hybrids are certainly present in North America. Hybrids occur in the wild, but more often they were produced in fish culture operations and subsequently escaped. In general, the habitat requirements of the all cichlids restrict them to warm climates and they will not survive typical winters in most regions of North America. Numerous species have become established in southern Florida and Hawaii. Some species have become established in parts of Arizona, Alabama, California, Texas, and other warm climates. Where these species occur in temperate climates, they are restricted to geothermal waters that provide suitable overwintering habitat.

None of the tilapiine cichlids have been reported from Devils Lake, any portions of the Red River of the North, or downstream waters. Therefore, water diversion from Devils Lake will not have an effect on the future distribution and abundance of these species.

3.5.1.7 Biology of PBOC: Parasites of Fishes

Parasites Identified as PBOC:

Cestoda, *Ligula intestinalis*
Monogenera, *Gyrodactilus hoffmani*
Acanthocephala, *Rhadinorhynchus sp.*

Life History and Distribution

The following life history descriptions are based upon Post (1987) and Hoffman (1999), with the latter used for classification. General distributions (e.g., North American states and provinces) are drawn from these two references. Presence in Hudson Bay drainages are drawn from lists in Sutherland and Holloway (1979), Reinisch (1981), Dick et al. (2001), and other literature and personal communications, as noted. However, these distribution lists are often incomplete because water bodies have not been examined, pathogens may have infected new hosts, or changing environments may have allowed infected hosts to colonize new areas (Dick et al. 2001). Thus, the distributions described below should not be viewed as definitive.

***L. intestinalis*:**

The Ligulidae are not highly host specific, either in the intermediate hosts (copepods and fish) or in the primary bird host (Post 1987). The primary hosts of *L. intestinalis* include many species of aquatic piscivorous birds such as gulls, herons, terns, grebes, loons and mergansers (Post 1987, Hoffman 1999). Adult worms may be from 10 to 100 cm when they are ingested with the infected fish. They mature in the bird intestine in as little as 35 to 40 hours, after which they produce eggs for two to four days and then die. The eggs are passed out of the primary host in feces and hatch to a free swimming coracidium (Post 1987). The coracidia are ingested by a wide variety of planktonic copepods (the first intermediate host) where they develop into procercoids (Post 1987). Second intermediate host fish species ingest the infected copepod and the procercoid penetrates the intestinal wall and enters the body cavity where it develops into a plerocercoid (Post 1987). The plerocercoid grows to fill the body cavity, the size of which limits the maximum size of the worm.

L. intestinalis is a ubiquitous parasite that is most commonly found in catostomids and cyprinids, but has been documented in various species of *Couesius, Etheostoma, Hybognathus, Micropterus, Mylocheilus, Notropis, Osmerus, Perca, Pimephales, Prosopium, Ptychocheilus, Richardsonius, Salvelinus, Siphateles,* and 30 other species (Hoffman 1999). This parasite has been reported on all continents (Post 1987). In North America, it is has been documented in most of the United States and the Canadian provinces of British Columbia, Alberta, Manitoba, Saskatchewan, Quebec, and New Brunswick (Hoffman 1999). Reinisch (1981) found this parasite in Devils Lake in *Pimephales promelas, Stizostedion vitreum* and *Esox lucius.* Sutherland et. al (1979) did not list this parasite among those found in the Sheyenne River. In the Hudson Bay drainage, it has been found in at least five species of fish in Dauphin Lake and the Heming Lake area (Dick et al. 2001).

***G. hoffmani*:**

The family Gyrodactlidae are a large group with five genera and over 140 recognized species, nearly all in the genus *Gyrodactilus* (Hoffman 1999). *Gyrodactilus sp.* are small external parasites that are rarely over 0.4 mm in length. They are hermaphroditic, viviparous, and complete their life cycle on a single host fish. Newly born young leave the adult with a completely formed genital system, ready to occupy a place on the host or to be transmitted by contact to a new host. They are usually found on the skin and less commonly on the gills of teleosts. They usually do no harm to the host except in situations that foster large infestations, such as fish culture with water of poor quality or overcrowded conditions (Post 1987). They can be transmitted laterally by direct contact or through the water.

Gyrodactylids are very host specific, with *Pimephales promelas* being the common host of *G. hoffmani* (Hoffman 1999). *G. hoffmani* has been reported from North Dakota (Holloway 1986) and from *Pimephales promelas* in Laurel Creek in Ontario (Molnar et al. 1974). It was found on *Pimephales promelas* in Devils Lake (Reinisch 1981). Sutherland and Holloway (1979) did not find *G. hoffmani* in the Sheyenne River, Lake Ashtabula, nor in Lake Winnipeg, although it is not known if *Pimephales promelas* were examined. *G. hoffmani*is reported to be common in Minnesota portions of the Red River of the North (Joe Marcino, Pathologist, MDNR, personal communication).

Rhadinorhynchus sp

The Acanthocephala are all endoparasites of vertebrate intestines. Fish are the primary host of most aquatic species, although fish are the secondary host of some species that use marine mammals as the primary host (Post 1987). They can be recognized by the barbed proboscis, the characteristics of which are often used to identify species (Hoffman 1999). This barbed proboscis may cause damage to the intestine if large numbers of worms are present in the fish. The life cycle is relatively simple and begins with eggs shed by the adult worm in the fish intestine. The eggs are ingested by a secondary crustacean host – typically a copepod, ostracod, amphipod, or isopod – where they bore into the body cavity and develop into a larval acanthella. Typically, the fish host becomes infected by eating the infected crustacean.

According to Hoffman (1999), the only described freshwater species in the genus *Rhadinorhynchus* is *R. trachuri*, which is found in anadromous salmonids. The remaining species of *Rhadinorhynchus* are found only in marine habitats. Furthermore, *R. trachuri* may be a marine parasite that shows up in anadromous fish that have entered freshwater to spawn

(Hoffman 1999). This parasite has been found in freshwater and marine habitats from California to British Columbia (Hoffman 1999). Reinisch (1981) identified *Rhadinorhynchus sp.* in Devils Lake in specimens of *Perca flavescens, Morone chrysops,* and *Stizostedion vitreum.* However, it seems unlikely that this parasite could have infected new host species in Devils Lake, far from the west coast of North America. These specimens may be misidentified Acanthocephalans in the closely related genus, *Letorhynchoides* (Terry Dick, University of Maintoba, personal communication).

<u>Potential Detection</u>

All of these parasites can be readily detected under the right circumstances. The parasitic worms *Rhadinorhynchus sp.* and *L. intestinalis* can be detected by internal examination of infected fish. The ectoparasite *G. hoffmani* can be detected from skin scrapings of infected fish. However, in all three cases the infected fish may show no outward signs of infestation. Therefore, there must be an active program to sample, and in some cases sacrifice, significant numbers of fish in order to detect these parasites. In cases where infection rates are low, large numbers of fish may have to be examined to determine presence of these parasites.

<u>Mechanisms for Movement</u>

Mechanisms for movement are very different among the three parasites. The distribution of *L. intestinalis* is very widespread due to the fact that it's primary host can be virtually any species of aquatic piscivorous bird, including gulls, terns, herons, grebes, loons and mergansers. Given this avian transmission vector, it is certain that *L. intestinalis* will spread to many waterbodies regardless of any future water diversion projects. On the other hand, transmission of *G. hoffmani* is restricted to contact with infected fish. Locations where it is absent may become infected by fish movements through connected water bodies, bait bucket transfers, stocking infected hatchery fish, or any other mechanism involving the movement of infected fish. Similarly, the transmission and spread of *Rhadinorhynchus sp.* also requires water contact – that is, infected fish, crustaceans (the intermediate host), or water containing viable eggs must move from one location to another.

<u>Ecological Niche</u>

All three parasites described here are commensal parasites that do not kill their hosts under normal environmental conditions. However, they reduce fitness of individuals and may detract from the overall health of populations.

<u>3.5.1.8 Biology of PBOC: Pathogens of Fishes</u>

Pathogens Identified as PBOC:

- **Myxozoa, *Myxobolus cerebralis* (whirling disease)**
- ***Renibacterium salmoninarium* (bacterial kidney disease)**
- **Microspora, *Heterosporis sp.* (heterospirosis)**
- **Infectious pancreatic necrosis virus (IPNV)**
- **Infectious hematopoietic necrosis virus**
- **Largemouth bass virus**
- **Pathogens of striped bass***

*All PBOC pathogens are addressed collectively below, except pathogens of striped bass. According to Harrell (1997), striped bass can be infected with many diseases, none of which have been reported from Devils Lake. These diseases do not differ greatly from those found in other fishes. It is very likely that striped bass no longer occur in Devils Lake, but an ongoing pathogen screening survey should be able to detect any of these diseases in striped bass or other species found in the lake.

Life History and Distribution

***M. cerebralis* (whirling disease):**

M. cerebralis is a myxosporidian that causes a disease commonly known as whirling disease or blacktail. According to Hoffman (1999), the life cycles of myxosporidians have been difficult to study because the direct fish-to-fish cycles are unclear. It was believed for many years that *M. cerebralis* required a period 3 to 3 ½ months of "aging" before being ingested via infected fish or fish based feeds. However, it has been shown that tubificid oligocheate annelids are the obligate intermediate hosts (Hoffman 1999). The disease is transmitted by ingesting the infected tubificid worms, particularly *Tubifex tubifex* (Thoesen 1994, Hoffman 1999). Cysts containing spores are deposited in the cartilage of the host and remain there until death when the spores are released from the decaying body or excreted from predators that may have eaten the infected fish.

M. cerebralis is found in the following salmonid species, with the most susceptible first: *Oncorhynchus mykiss, O. nerka, Salvelinus fontinalis, O. tshawytscha, Salmo salar, S. trutta, O. kisutsch, S. namaycush* (Hoffman 1999). Young fish are more susceptible to infection and show greater rates of morbidity and mortality (Post 1987, Hoffman 1999). Infected brown trout and coho salmon may show no signs of the disease, particularly if infected at over one year of age (Post 1987, Thoesen 1994). Other species (e.g., *Lepomis sp.*) have been intentionally infected in laboratory conditions (Hoffman 1999).

M. cerebralis was first identified in Germany (Post 1987). Since then, it has been found in numerous European locations, as well as Russia, Asia, South Africa, New Zealand, South America and North America (Post 1987, Thoesen 1994). The first occurrence in the United States was in 1956 in Pennsylvania as a result of importing infected frozen trout (Post 1987). The pathogen subsequently appeared in the states of California, Colorado, Connecticut, Idaho, Massachusetts, Michigan, Montana, Nevada, New Hampshire, New Jersey, Ohio, Oregon, Utah, Virginia and West Virginia (Post 1987, Thoesen 1994). *M. cerebralis* has not been detected in Devils Lake.

***R. salmoninarium* (bacterial kidney disease):**

R. salmoninarium is a bacterial disease commonly known as bacterial kidney disease (BKD) in North America. It is an obligate parasite and is not thought to survive well outside the host. It grows best at temperatures between 4 °C and 20.5 °C with more rapid progression at higher end of this temperature range (Thoesen 1994). The disease is more prevalent among susceptible fishes in soft water conditions than in hard water conditions (Post 1987). In hatchery situations, certain diets may influence the progress of the disease (Thoesen 1994). It can be transmitted vertically and horizontally. Acute and subacute forms of the disease occur only sporadically. More typically, the disease is chronic, frequently characterized by an enlarged kidney with one or more lesions (Thoesen 1994). The disease sometimes attacks other organs. Routes of transmission are not known with certainty, but oral and cutaneous transmission may occur (Post 1987).

Infected salmonid populations are believed to be the principal reservoir of infection (Thoesen 1994). Susceptible species probably include all species of salmonids (Post 1987). Infected anadromous salmonids retain the disease in saltwater (Thoesen 1994), where mortality may even be greater than in freshwater (Post 1987). Spontaneous *R. salmoninarium* is not often found among wild salmonids, although the disease can be transmitted to wild fish from infected hatchery fish (Post 1987). Possibly, low pathogen concentration in large water bodies may not be conducive to transmission from fish to fish (Post 1987).

R. salmoninarium is found on every continent (Post 1987, Thoesen 1994). In North America, it has been reported from many locations where salmonids are cultured, both in the United States and Canada (Post 1987).

***Heterosporis sp.*:**

Heterosporis sp. are intracellular protozoan parasites in the phylum Microspora. According to Hoffman (1999) there are only two species in this genus, and these are only known to infect freshwater aquaria fishes in Europe. Fish are infected by spores that penetrate the cell wall with a polar tube which passes the infective agent (sporoplasm) to the host (Hoffman 1999). Once in the bloodstream or body cavity, the sporoplasm is carried to the site of infection. Outbreaks in North America have typically progressed from anterior muscle tissue through the entire body, with the production of meronts and spores causing the flesh of the host fish to take on a milky, "cooked" appearance (IDFW 2000, WDNR 2000). Infected fish show no outward signs of infection. It is not known how long a fish may live with the infection or the degree of mortality the disease may cause in different species of fish. Spores may be released from the skin of infected fish (Lom 2000) or from the body when diseased fish are consumed or die (IDFW 2000, WDNR 2000). Spores may remain viable outside the host for at least a year (WDNR 2000).

In North America, *Heterosporis sp.* was first documented in about 1999 in Wisconsin and Minnesota (Sue Marcquenski, Wisconsin DNR, personal communication). In Wisconsin, it was found in yellow perch in the Eagle River Chain of Lakes (IDFW 2000, WDNR 2000). In Minnesota, the parasite was found in walleye in Leech Lake and Vermilion Lake (WDNR 2000). Follow-up sampling in the Eagle River Chain of Lakes found that 10% of the yellow perch were infected but no infected walleye were found (WDNR 2000). Similar results were found in Catfish Lake in Wisconsin, where 30% of sampled yellow perch were infected but none of 105 walleye tested positive for the disease (WDNR 2000). Based on these results, it appears that yellow perch are much more susceptible to the disease than walleye.

Infectious pancreatic necrosis virus:

Infectious pancreatic necrosis virus (IPNV) is a birnavirus that is primarily associated with salmonids in fish culture settings (Thoesen 1994). In salmonids, acute IPNV infections occur in one to four month old fish, and can result in cumulative mortality that approaches 100% (Thoesen 1994). Mortality develops rapidly at temperatures of 10-14 °C, is protracted at lower temperatures, and can be reduced at higher temperatures (Post 1987, Thoesen 1994). Older fish may have subclinical infections with no symptoms and negligible mortality – this is especially true in those cases where the disease is present in wild salmonid populations (Thoesen 1994).

Survivors become repositories for the virus, shedding it in feces, urine and sex products (Post 1987, Thoesen 1994). Acute infections attack the pancreatic, renal, intestinal, and hepatic tissues. Acute cases commonly involve necrosis of the pancreas and anterior intestinal tract, including the pyloric caeca (Thoesen 1994). IPNV can be transmitted vertically with eggs – this has been implicated in numerous fish culture transfers of the disease – and horizontally from infected fish (Post 1987). The virus survives well outside the host fish and has been found to pass through the gut of fish eating birds and mammals, which may spread the virus to uninfected water bodies (Post 1987).

IPNV and IPN-like viruses have been recovered from at least 67 freshwater and marine species, representing salmonid fishes, non-salmonids fishes, crustaceans, and molluscs (Thoesen 1994). IPNV has been associated with mortality in striped bass fry, southern flounder, Atlantic silverside, spot, Atlantic croaker, silver perch, hogchoker, and striped mullet, all in estuarine waters (Post 1987). IPNV has caused severe mortality in eel alevins in Europe and Japan (Post 1987). IPNV has been found in apparently healthy asymptomatic specimens of white sucker, carp, perch, roach, bream, pike, discus fish, zebra danio, and goldfish (Post 1987).

IPNV has been distributed worldwide, apparently as a result of fish culture operations involving infected fish (Post 1987, Thoesen 1994). According to Post (1987), the disease first appeared in North American in the northeastern United States and "…has subsequently been diagnosed throughout the trout-rearing and some salmon rearing areas of the United States and Canada."

Infectious hematopoietic necrosis virus:

Infectious hematopoietic necrosis virus (IHNV) is a rhabdovirus disease of salmonids that is considered to be enzootic throughout the west coast of North America and the islands of Honshu and Hokkaido in Japan (Thoesen 1994). Young salmon up to two months of age are the most susceptible to infection (Thoesen 1994). The virus attacks the hematopoietic tissue of the spleen and anterior kidney, although other tissues of the body become target organs as the disease progresses (Post 1987). The disease is most common at temperatures of 12 °C or less, although outbreaks have occurred at temperatures up to 15 °C (Thoesen 1994). Higher temperatures cause signs of the disease to cease (Post 1987). Fish that survive epizootics as juveniles may show no further signs of the disease and a high percentage of the survivors have been reported to become carriers for the remainder for their life (Post 1987, Thoesen 1994). The disease is transmitted horizontally by contact with infected fish or water (Post 1987, Thoesen 1994). Natural epizootics among wild salmonids have not been reported (Post 1987).

IHNV is restricted to salmonids, particularly *Oncorhynchus sp.* – the disease is most often reported in both the freshwater and anadromous strains of sockeye salmon, chinook salmon, and rainbow trout (Thoesen 1994). It has also been reported in Atlantic salmon, chum salmon, cutthroat trout, and occasionally in brown trout (Thoesen 1994). According to Thoesen (1994), epizootics also occur among the species of *Oncorhynchus* found in Japan (amago, yamame, and chum salmon). Although brook trout have been shown to be susceptible to IHNV, in general, *Salvelinus sp.* are somewhat resistant to the disease (Thoesen 1994).

IHNV is widespread in areas where *Oncorhynchus sp.* salmonids are reared in hatchery facilities (Thoesen 1994). Thus, the west coast of North America from California to Alaska has had numerous epizootics of IHNV. In Japan, IHNV epizootics have occurred in salmonid culture facilities on the islands of Honshu and Hokkaido. The movement of infected fish products between North American hatcheries has also resulted in outbreaks in Colorado, Minnesota, Montana, New York, South Dakota, West Virginia and Virginia (Thoesen 1994).

Largemouth bass virus:

Largemouth bass virus (LMBV) is a relatively new disease and many questions remain unanswered. It is an Iridovirus in the genus *Ranavirus*, related to a virus found in frogs and other amphibians (MR 2001). Genetically, LMBV is 98% similar to a virus found in some imported aquaria fish, leading some to conclude that it may have been imported via aquaria fish (TPW 2000). Largemouth bass may carry the disease for years without acute effects or even any symptoms (TPW 2000). It may only progress to acute stages and cause mortality when other stressors, such as excessively high water temperature, poor water quality, capture and handling, or pollution, make the fish more vulnerable (MR 2001). Fish kills attributable to LMBV have been documented in 20 locations, all in the southern United States (TPW 2000). The virus remains viable for 3-4 hours outside of the host fish, indicating that it may be possible for it to be transferred in boats or live wells that held infected fish (TPW 2001). Adult fish appear to be affected more often than juveniles. LMBV attacks the swim bladder and moribund fish may appear bloated and unable to maintain balance (TPW 2000).

LMBV is found in many centrarchids, but only largemouth bass are affected (TPW 2000). LMBV has been found in spotted bass, Suwanee bass, bluegill, redbreast sunfish, white crappie, and black crappie (TPW 2000). Sampling of about 3,500 largemouth bass and centrarchids in nine states in 2000 found an infection rate of 13% (TPW 2000). During a recent study, LMBV was present in 5% of the fish in 14 lakes in Texas, although none of the infected fish exhibited any symptoms (TPW 2001).

LMBV was first discovered in Santee-Cooper Reservoir in South Carolina in 1995 (TPW 2000). Since then it has been found in many locations and may have been present for many years. It has been documented in the states of Alabama, Arkansas, Florida, Georgia, Indiana, Kentucky, Louisiana, Michigan, Missouri, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas (TPW 2000). The most northern location that the virus has been detected is Lake George on the Indiana/Michigan border (IDFW 2000). During 1997-98, a monitoring program covering 75 lakes in eight southern states detected the virus in six locations (MR 2001). A recent study in Texas documented LMBV in 14 of 49 lakes sampled, encompassing two thirds of the Texas watersheds (TPW 2001).

<u>Potential Detection</u>

All of the fish diseases described above can be detected by the appropriate assays and/or microscopic examinations. Confirmatory diagnoses of *M. cerebralis* and *Heterosporis sp.* require specific assays in order to identify the spores. The bacterial disease *R. salmoninarium* can be identified by the symptoms and the presence of gram positive bacteria. The three viral diseases described above (IPNV, IHNV and LMBV) can each be detected by specific assays.

M. cerebralis, *R. salmoninarium*, IHNV and IPNV are most often detected in hatchery situations. The other two diseases, *Heterosporis sp.* and LMBV have been found mostly in wild populations. However, all of these diseases are similar in that they do not generally exhibit symptoms until infections are acute and many individuals are affected. They also are similar in that infected fish may be asymptomatic and carry these diseases for long periods – years in the case of certain species of fish. Carrier fish include, but may not be limited to, the following species for each of the diseases; centrachids for LMBV, yellow perch for *Heterosporis sp.*, many marine and freshwater species for IPNV, and most salmonids for the other three diseases. Because of these carriers, and the fact that infected fish may be asymptomatic for long periods, potential detection in wild fish populations requires specific sampling and testing to detect these diseases before epizootics occur.

Mechanisms for Movement

The mechanisms for movement (i.e., transmission) of these diseases may be direct or indirect. The direct route is via the host or connected waterways while the indirect route involves humans or natural processes. In the case of humans, this includes the movement of bait fish, enhancement or stocking programs, and aquaculture (Dick et al. 2001). The illegal release of bait fish has a high probability of introducing some of these diseases due to the cumulative effect of millions of angler days of fishing effort using live bait (Ludwig and Leitch 2001). Stocking hatchery fish, particularly salmonid stocking programs, also have a high probability of introducing diseases since four of these diseases are most often found in hatchery settings and infected fish may show no symptoms.

Direct routes of transmission include the movement of infected fish through connected waterways and disease transmission. Most of these diseases can be transmitted from fish to fish. Only *M. cerebralis* has an obligate intermediate host (tubificid worms). *M. cerebralis* is apparently transmitted to fish by ingesting infected tubificid worms (Thoesen 1994). The worms are infected by ingesting active spores that were released from infected fish or were contained in fish products (e.g., feeds containing infected fish). Spores can remain viable for long periods of time (months to years).

According to Post (1987), *R. salmoninarium* transmission from hatchery fish to wild fish may be more prevalent than previously thought considering the wide distribution of infected cultured fishes over the past decades. Infected salmonid populations are believed to be the principal reservoir of *R. salmoninarium* infection (Thoesen 1994). There is also some uncertainty whether *R. salmoninarium* can be spread via birds or mammals (Post 1987).

In the past few years, *Heterosporis sp.* has been found in several Minnesota and Wisconsin lakes. There is a great deal of uncertainty about the routes of transmission of *Heterosporis sp.* – while it is known that it can be passed from fish to fish, other routes of transmission cannot be ruled out yet (Sue Marcquenski, Wisconsin DNR, personal communication). *Heterosporis sp.* spores remain viable for at least a year. Spores may be shed by infected fish but certainly at death or when infected fish are consumed.

The viruses IPNV and IHNV are similar in that fish culture has spread these diseases over wide geographic areas. Many species of fish may carry IPNV and spread this disease. Many salmonids can carry IHNV, and this disease has been spread widely throughout in western North America as a result anadromous salmonid stocking (Thoesen 1994). Fish eating birds and mammals may also spread these diseases.

LMBV has been found in many southern lakes and reservoirs over a few years. The widespread distribution of this disease has lead researchers to believe it may have been present for some time (MR 2001). The mechanism of transmission is not know with certainty, but it is believed that

LMBV is transmitted directly from fish to fish. The virus only remains viable for 3-4 hours outside of the fish host. Various centrarchids are a significant reservoir for the disease since they can carry the disease without symptoms or acute effects.

Ecological Niche

The diseases described here are not necessarily fatal. Depending on the disease in question, epizootics typically have occurred in crowded hatchery settings, with poor water quality, or among young fish. These diseases control populations by reducing dense concentrations in time and space.

3.5.1.9 Biology of PBOC: Pathogens of Non-Fish Vertebrates

Scientific name: *Clostridium botulinum* (Type C)
Common name: avian botulism bacterium

Life History and Distribution

Avian botulism is a disease that kills hundreds of thousands of ducks per year in the United States and Canada. *Clostridium botulinum* is a bacteria that exists widely in wetland soils and is spread by birds. Production of the *C. botulinum* toxin, which is highly toxic to birds, involves a complex life cycle requiring several organisms, including *C. botulinum,* one of many putrefactive bacteria that function as decomposers in the ecosystem (Leighton 2000).

The botulism spore or resting stage of the bacteria is often found in wet soils, and many birds inadvertently eat the spores while feeding. The spores then live in the birds' tissue without causing any ill effects. However, when the bird dies, its decaying carcass offers three conditions *C. botulinum* needs to grow and produce toxin: high temperatures, protein-rich material, and an absence of oxygen (Environment Canada 2001). The growth of *C. botulinum* is also favored by alkaline conditions.

Avian botulism is caused when a virus infects type-C *Clostridium botulinum* and causes the bacteria to produce a neurotoxin. Botulism toxin is transferred to birds by maggots and other invertebrates that feed on the decaying carcasses. Toxin accumulates in the maggots to levels that can kill a duck. Large numbers of maggots on a bird carcass can attract more live birds. The birds are then poisoned by ingesting toxic maggots.

Avian botulism is widespread in North America. The largest and most severe outbreaks have occurred in the western part of the continent, generally within the major flyways for migratory waterfowl. Large outbreaks have been recorded in southwestern Manitoba, Saskatchewan, North Dakota and Wisconsin, killing up to one million birds in one instance (Leighton 1999).

Potential Detection

Avian botulism becomes evident in the behavior of affected birds as they become paralyzed by the neurotoxin. Ducks with avian botulism are poisoned slowly weakening the birds muscles and making them unable to fly or even swim in the late stages. Eventually the toxin cause neck paralysis and the birds are unable to support their own heads (Leighton 1999).

Leighton (2000) states that live, sick birds must be tested in the lab to verify the presence of the disease: "A definitive diagnosis of Type C botulism requires that Type C botulinum toxin be found in the blood of a live, clinically-affected (sick) bird. Finding the toxin in the heart blood of a very freshly-dead bird is evidence that the bird may have died of botulism, but it also is possible that the toxin that is detected was produced after death during putrefaction, and that it had nothing to do with the death of the bird."

Because of the cyclic nature of the disease, it is possible for just a few dead birds to spread the infection to thousands of birds. Large die-offs of birds may also be indicators of an avian botulism infection. At this point detection is well past the point of preventative action. In small lakes or wetlands that are intensively monitored, early removal of dead, infected birds may prevent further spread.

Mechanisms for Movement

Avian botulism is transported by infected ducks. Birds carrying the resting spore stage are not adversely effected and so can widely spread the bacteria. However, when the ducks die, the bacteria reproduce and maggots may bio-accumulate the C botulism toxin. Birds are attracted to maggots as a source of food, thus facilitating the spread of the disease.

Ecological Niche

As a decomposing bacterium, *C. botulinum* functions to break-down higher-level consumers and provide nutrients for primary producers and food for lower-level consumers. An outbreak of botulism does not happen every time an animal dies in a wetland. Many environmental factors can affect whether or not an outbreak of botulism will occur on a marsh. Some of these factors are the frequency with which animals die (for any reason) in the environment, the speed with which scavengers remove carcasses before they putrefy and produce toxin and maggots, the amount *Clostridium botulinum* (Type C) in the environment, the number and density of birds in the environment (which will determine how likely it is that birds will encounter and feed on the maggots on a carcass) and ambient temperature (which influences rates of decomposition, toxin production and fly activity) (Leighton 2000). The spread of botulism is a complex ecological phenomenon dependent on the interaction of a large number of different biological and physical factors.

3.5.2 Effects of Devils Lake Habitat Changes on PBOC

The recent Devils Lake size and depth expansion has seen a concomitant expansion of aquatic habitat quantity and diversity. These new or expanded habitats can be assumed to have been invaded by many species already present in Devils Lake, but also could be occupied by invading species, or by species that had previously been locally rare, but take advantage of new, favorable habitats. Given the magnitude of habitat change in the system, the biotic community almost certainly differs somewhat from those described in published studies.

3.5.2.1 History, Landscape Context, and Habitat Conditions

Devils Lake is in the northern tall grass prairie biotic region. The area experiences the short hot summers and long cold winters of the continental climate of the northern Great Plains. Precipitation is normally less than 25 inches per year, much of which is delivered as snowfall. The combination of the brief and often dry growing season and a landscape graded flat by repeated glacial advance naturally minimizes the regional habitat opportunities favoring vascular plant diversity. Much of the better drained landscape, formerly dominated by a relatively few, but vigorous, species of grass, sedge and tall herb, is now almost entirely cropped or grazed. This has further reduced species diversity to those few species unpalatable to domestic herbivores or those which survive as early-successional field weeds. Wetter areas (the “Prairie Potholes”) offer greater plant diversity opportunities, however agricultural effects and recently rising water levels have typically yielded eutrophic basins ringed with cattail monocultures and scattered patches of waterweed. Trees, represented regionally by only six species, are now generally confined to fencerows and stream channel fringes.

As the region’s largest of the myriad of glacially excavated pothole lakes, Devils Lake has the character of an oasis in a otherwise uniform prairie-agriculture landscape. The product of particularly massive glacial gouging is the unexpected topographic relief, often of more than 300 feet above the surrounding prairie, provided by morainic hills along the south and east shores of the lake. These hills provide a diversity of soil and drainage conditions that supports both forest (of still only six species) and greatly enhanced shrub and herbaceous species diversity.

Devils Lake is typically a closed basin, receiving surface water runoff from about 3,810 square miles to the north and west of the lake. Former water levels, balanced at an elevation about 50 feet lower than observed today and mesosaline, supported aquatic and fringing emergent halophytic communities. Since water levels have risen about one foot per year since 1950, resulting in progressive lake-water dilution, halophytes are rapidly declining in importance. All other aquatic and lake-fringing plant communities are also experiencing significant change as waters have become both less saline and much deeper.

The effects of the natural circumstances of topography, climate and soil and the extended wetter than normal (pluvial) period on adjacent land uses and land cover is extreme. Former mesosaline marsh has become barren lake bottom. Fresh emergent marsh has transitioned to floating aquatic communities, wet prairie has transitioned to extensive stands of cattail and bulrush (Figures 3A and 3B). Low, fringing forests of ash, cottonwood and basswood have become inundated forests of dead “snags,” which, provide improved fish and wood duck habitat (Figure 5A). In some wave-washed areas, mud flat shoer zones have formed from sediment (Figure 5B). The overall effect of rising water levels has been the accretion of wet-successional plant communities along the entire fringe of the lake. The type of new plant community accruing, extent to which the changes have occurred is directly related to the topography of the lakes’ fringe. The steeper slopes along the east and south sides limit aquatic succession; however sloughing banks are providing ever-widening emergent shorelines in many areas. Extensive and relatively flat areas of crop and grazing land along the western side have become nearly unbroken stands of cattail, stretching now for miles.

While no land cover map can fully represent the instant effects of this rapidly changing conditions at Devils Lake, Figure 2 illustrates the most recently compiled land cover types in the area. The accuracy of land cover units as mapped declines with decreasing proximity to the lake.

<u>3.5.2.2 Responses to Water-Level Rise</u>

In 1993, at the beginning of the recent dramatic water-level rise, Devils Lake covered about 44,000 acres. At an elevation of 1446.5 feet above sea level, the lake covers about 119,000 acres, and begins to overflow to Stump Lake. The lake exceeded this elevation at its 2001 peak, though it has receded slightly since then. Of the 75,000 acres of land flooded since 1993, the majority were crop and rangeland, but some deciduous forest areas, especially south of Main Bay, and large expanses of wetland to the west were flooded (See Figure 2).

Flooding of land surrounding Devils Lake has expanded the littoral zone of the lake dramatically, and has diluted the lake resulting in lower salinity in most areas. Most of the land flooded (former forest, wetland, and farmland), probably had nutrient-rich organic soils that should provide very fertile benthic substrate for growth of aquatic biota. In fact, many portions of the newly forming lake fringe, particularly inundated agricultural lands, appear to support eutrophic conditions. Such areas, are often heavily colonized by duckweed (*Lemna trisulca*) and one or more species of Cyanobacteria (blue-green algae), both of which thrive under nutrient enrichment, and are considered indicators of eutrophication, as described below (Figure 5A).

Much of the area east of the lake, depicted as “non-forested wetland” in Figure 2, is now open water, and much of the noted “herbaceous range” is now cattail marsh, so loss of emergent plant habitat in some areas has been compensated by new habitat further upslope. The net result is that "open water" habitats have increased in areal extent, which may favor planktonic biota and deeper-water benthic organisms. Also, open-water, pelagic habitats are usually successfully exploited by some fishes, particularly white bass, walleye, and yellow perch (Owen et al. 1981, Peterka and Koel 1996), as well as the larval stages of many species and schooling shiners, which may now exist in Devils Lake as a result of baitfish introduction.

The forest edge has receded along most of the lake fringe, leaving a standing snag forest ranging from a few score to a few hundred feet in width (See Figure 4A). This has probably created valuable submerged structure for fishes, but only moderately favorable habitat for small fishes, juveniles of larger species, and macroinvertebrates. Emergent and submergent non-woody plants provide better predation refuges for these animals than they can find in the open spacies between submerged trunks of mature trees. However, those portions of submerged forest that are dominated by dead shrub thickets probably provide fairly favorable habitat for these smaller animals.

The area along the increasing lake water level was found to be a transitional assemblage of plants composed of early hydrarch successional hydrophytes (recently invading annual and short–lived perennial wetland plants) or water-stressed non-wetland species, depending on the time since saturation or inundation. While lower-gradient shorelines have become floating or rooted aquatic beds and cattail stands, hence valuable animal habitat, the more wave-exposed, areas have become barren shoreline (See Figure 4B). Highly wave-swept shorelines do not develop macrophyte communities, and are favorable habitat for only a minority of organisms: mostly benthic algae and interstitial meiofauna. More protected shorelines that are currently deviod of vegetation will be colonized by plants very soon, initiating the successional sequence if wave exposure is not too great. Within a year or two, the fecund and aggressive cattails take over these sites because they are adept at invading disturbed and nutrient-rich substrates. Broad-leaved cattail (*Typha latifolia*) seems to be the dominant species found, while the introduced hybrid *Typha* X *glauca* is reported to be increasing in importance throughout eastern North Dakota (DeKeyser 2000). Figure 3B depicts the typical cattail-dominated shoreline. The invasive grasses common reed (*Phragmites australis*) and reedgrass (*Phalaris* sp.) occur occasionally in these marshy shoreline communities. Both of these species are exotic, but widely distributed and well-established throughout the region. With cattails and these two grasses dominating, these new marsh communities cannot be considered highly valuable in terms of biodiversity or overall habitat quality, yet they should be highly productive in both primary and secondary productivity, so fishes and waterfowl will find abundant food in these areas.

Because connections between East Devils Lake and Black Tiger Bay are restricted by road crossings, these areas remain mesosaline (Figure 5B). Cattail is held in check, although clearly incipient, while halophytic communities retain some narrow shoreline. Dominant species include halophiles such as the cordgrasses (*Spartina pectinanta*, and S. *gracilis*), salt-marsh hay (*Distichlis spicata*), spearscale (*Atriplex patula*), alkali grass (*Puccinellia nuttalliania*), arrow-grass (*Triglochin maritima*) and glasswort (*Salicornia rubra*). The few remaining occurrences of the floating aquatic species ditchgrass (*Ruppia maritima*) are also found in these areas. While not directly observed, it is reasonable to predict that halophilic algae and other organisms may also find in this part of the lake a refuge from the trend toward freshening, or less saline, water.

As shown in Figure 3A, bulrush and sedge associations often occupy shorelines in the Main Bay, central portion of Devils Lake. Important species include American rush (*Scirpus pungens*), soft-stem bulrush (*Scirpus validus*), riverine bulrush (*Scirpus fluviatalis*) and several species of the genera *Carex* and *Eleocharis*. Species often found in these stands include the weedy sow thistle (*Sohchus arvensis*), red goosefoot (*Chenopodium rubrum*) and pale goosefoot (*Chenopodium glaucum*). The edge of an extensive bed of the most common waterweed observed, Sago pondweed (*Potamogeton pectinatus*), is also shown in Figure 3A. This assemblage of emergent species and the submergent *P. pectinatus* should provide a very favorable habitat for many invertebrate, attached algae, and small fish species.

Overall, the expansion of Devils Lake has created much greater habitat diversity than reported in previous treatments, particularly that of Young (1924). While Young's (1924) work was the most complete account found, it described a lake experiencing processes the opposite of those that have dominated the lake recently. Habitat diversity in lakes results from diverse physical and chemical factors, and by biotic processes and structural features maintained by plant communities. Habitat diversity in Devils Lake largely depends on the new diversity of shoreline conditions. For example, different prior uses of lands that formerly surrounded the lake but are now submerged create a variety of soil richness conditions and physical structure (from submerged woody vegetation) around the lake. Further, the highly convoluted shoreline creates a vast array of wave-exposure conditions. Wave exposure affects littoral vegetation and pelagic and littoral turbidity and chemistry, both of which affect biota.

Increased habitat diversity alone can be responsible for substantial increases in species diversity, but other factors have probably played major contributing roles as well. The vast expanse of newly flooded warm, shallow habitat has provided much new, fertile habitat space for many species, and larger areas can be expected to harbor larger numbers of species. They also provide a much larger "target" for those species that are passively transported into new habitats by wind and weather events.

Finally, the freshening trend has certainly encouraged growth in species diversity. High salinity is stressful for most non-marine aquatic species, and marine species are rare in Devils Lake, due to its distance from any ocean. Reduced salinity opens Devils Lake habitats to the rich pool of true freshwater species present in North Dakota. These influxes of new species must certainly outnumber the species losses that occur as salt-adapted species probably must give way to competetively superior fresh water invaders. These assumed species invasions will probably continue because the prairie potholes of North Dakota harbor a rich reservoir of species that have adapted to escape or endure harsh conditions and to disperse among waterbodies by wind or other physical mechanisms.

3.5.3 Existing Pathways for PBOC Transfer Between Basins

The question of biota transfer from Devils Lake to the Sheyenne River must involve consideration of the likelihood that Devils Lake species can already be transferred across the basin boundary by "natural" means. This is an especially relevant question because (a) the DLB is a sub-basin of the Red River drainage so communities are expected to be similar in both areas, (b) the sub-basin watershed is low in elevation, providing little hindrance to "vehicles" of passive dispersal, and (c) distances between surface waters of the two basins are small, especially under present high-water conditions when lakes have expanded and many low areas have become wetland or moist-soil environments.

Natural dispersal of freshwater organisms across land barriers has long been a topic of discussion and research (succinctly reviewed by Maguire 1963 and Round 1981), but many taxon-specific rate-related questions remain unanswered. It is clear that such dispersal occurs and has done so with and without human influence. Many of the same species are found in water bodies seperated by substantial distances and having no direct water connections. In fact, aquatic biota are often considered more widespread across regions and continents than terrestrial biota. If this is true, it attests to such remarkable dispersal abilities in most aquatic species that it can appear that many such species appear from nothing (as many past proponents of spontaneous generation suggested). For example, it takes little time (< 3 yrs.) for newly filled reservoirs (Thouvenot et al. 2000), experimental ponds (Jenkins 1995), and even new volcanic islands (Maguire 1977) to become occupied by immigrating organisms such as rotifers, copepods, and cladocerans, with many species appearing within the first year.

Several mechanisms of overland transport of aquatic organisms have been confirmed (as discussed in detail below). However, the effectiveness of various dispersal mechanisms remains to be determined. The question of how long it may take for a species to be passively dispersed into new habitats cannot be answered with any confidence at present. Passive dispersal by any particular mechanism is apparently more effective for some species than for others, and passive dispersal in general may be less frequent than many have suspected (Jenkins and Underwood 1998).

Some researchers have contested the notion of easy and frequent overland dispersal of aquatic organisms. Jenkins and Underwood (1998) found lower-than-expected numbers of aquatic organisms in wind, rain, and bird fecal samples. They did not challenge the assertion that small organisms can disperse across land, but distinguished between "potential" and "actual" dispersal, i.e. the ability of individuals to be transmitted vs. such transmission occurring at high enough frequencies to saturate a landscape with immigrants of all species in the regional pool. Another criticism was put forth by Frey (1982), who noted that the term "cosmopolitan" may often be overused in reference to zooplankton species because detailed taxonomic work has resulted in some widespread "species" being re-classified as groups of sister species with different geographical ranges. This suggested that successful dispersal events may happen infrequently, so gene flow is curtailed and separate populations can diverge through allopatric speciation. However, hybridization zones can occur where species distributions meet, maintaining some level of genetic connectivity among sister species and/or subspecies (Chen et al. 1997).

Despite the above-noted reasons for skepticism regarding universal dispersal, the distances between waters of the DLB and RRB are very short relative to the distributions of all PBOC species, and means of dispersal discussed below are abundant in eastern North Dakota, so it seems reasonable to assume that natural pathways between the basins are, and have been, effective means of biota transfer for a very long time. As an example, several PBOC algae species have marine origins, yet they occur in North Dakota, far from any ocean. After having dispersed so far, they must also be able to reach the waters of the RRB.

A compelling piece of evidence suggesting that Devils Lake species can readily disperse into the Sheyenne River is the presence of several PBOC algae species in both the lake and in the Cottonwood Lakes Area (CLA), about 70 or so miles away (LaBaugh and Swanson 1988). The CLA is in the Missouri River drainage, and the Sheyenne River flows west to east between Devils Lake and CLA. The river then turns south, coming within 50 to 60 miles of the CLA. Any PBOC species present in both waters must be able to disperse farther than the distance to the Sheyenne River, which is closer to both than they are to each other. It follows that these algae have had overland pathways for passive dispersal to and over the Sheyenne River, and probably continue to exploit these pathways periodically.

3.5.3.1 Natural Mechanisms

Because few, if any, truly aquatic organisms can actively migrate among basins, authors have proposed several passive transport mechanisms for aquatic biota, most of which have been supported by scientific study and other documentation:

Wind dispersal. Wind can transport organisms great distances. Dessication-resistant life stages or propagules can be lifted from water surfaces and spray or from the dried sediments at water-body margins or in drawn-down temporary-water basins (Bold 1978, Trainor 1978). Even non-resistant life stages can be transported by wind-borne spray over short distances.

Protozoa, algae, plants, and the majority of freshwater micro- and meioinvertebrates (e.g. rotifers, many flatworms, most small crustaceans) are known to produce dessication-resistant life stages, such as resting eggs, encysted or coccooned juveniles or adults, seeds, spores (algae), or perrenating bodies (submergent plants). These can lie in submerged or exposed sediments "waiting" for favorable conditions, or they can be blown to other areas, with some randomly falling in water bodies. Brine shrimp, *Artemia salina*, have depended on this dispersal mechanism to colonize the widely dispersed saline inland water bodies around the world (Pennak 1989), and the related fairy shrimp, *Branchipodopsis wolfi*, has been shown to disperse by the same mechanism, though perhaps only over shorter distances (Brendonck and Riddoch 1999). The phenomenon of "airborne algae" has been well documented (Trainor 1978), and includes unicellular and colonial forms of moist-soil and fully aquatic species. These algae can be found almost everywhere, even in household dust (Bold 1978), and can start new populations anywhere that they find sufficient moisture and exposure to sunlight.

Wind is likely an important means of passive transport in the DLB and RRB because the region is relatively windy and because surface water in the region are subject to frequent hydrologic fluctuations. These fluctuations induce biota to enter and leave dessication-resistant resting stages, and they expose these stages and other propagules to wind exposure as waters alternately rise and recede. Also, distances among surface waters of the two basins are short, especially in the current wet period, and basin divides are low, so even non-dessication-resistant stages are likely to be transported from one basin to another before drying out.

Animals. Large and mobile animals serve as vehicles for many micro- and meiobiota, and even macroinvertebrates and plant parts. Mechanisms of such transport are many (Pennak 1989, Thorp and Covich 1991), including active "hitchhiking" by amphipods and juvenile mussels ("glochidia") in bird feathers, inadvertent transport of endo- and ectoparasites and parasitoids attached to mobile hosts, transport of digestion-resistant would-be food organisms in predators'/grazers' guts, and passive pickup of organisms occurring in water and benthic mud that adhere to visiting animals' fur, feathers, and body cavities and crevices. Fur and feathers can provide warm, moisture-retaining compartments in which small organisms can ride to new habitats, but animals other than birds and mammals are effective dispersal vectors also. At least 23 species of beetles (collectively) have been found passively carrying algae from 101 genera (Bold 1978). Viable propagules and cysts of various invertebrates and algae have been found in the feces of many animals including salamanders (Bohonak and Whiteman 1999), and waterfowl (Proctor 1964). Proctor and Malone (1965) found that life stages of several aquatic organisms could even survive the digestive tracts of some unlikely dispersal vectors: pigeons, chickens, and canaries (Proctor 1964). Those propagules (or "disseminules" *sensu* Proctor and Malone 1965) found included oospores of two species of the macroalga genus *Chara*, and resting eggs of brine shrimp and two species of ostracods.

Animal transport of aquatic biota in the Devils Lake and DLB and RRB is likely a very important mechanism connecting the biota of the basins. The region lies within a major waterfowl flyway, so the annual number of bird visits per water body must be extremely high. Also, the low basin divides make interbasin mammal, reptile, amphibian, and insect travel relatively easy, and the large number of surface water bodies, including wetlands, create a dense mosaic of favorable habitat patches for aquatic biota, so species dispersal over long distances can be accomplished as branching series of small "hops" over long periods of time.

Rare meteroological events. Though uncommon, floods, tornadoes, and other such natural "disasters" can transport aquatic biota from one basin to another. The most extreme examples of this phenomenon are the "rains" of fishes and frogs that have been lifted in waterspouts, carried overland in airborne storm systems, and deposited elsewhere. If such storm systems can transport macrovertebrates, they can be assumed to even more frequently transport micro- and meiobiota that escape detection by non-scientists.

Weather in the DLB and RRB region can be relatively violent and erratic, and storms are common, so meterological transport may be more important than in some other regions, but still a relatively rare type of event.

Subterranean waters. In some cases, subsurface water connections between basins exist, and support groundwater fauna, from bacteria to meiofaunal invertebrates. Obligate photosynthesizers are excluded from such biota because they require sunlight, although ongoing research is finding chemosynthesizing primary producers to be more common in subterranean systems than previously thought. Despite the growing literature on groundwater and troglodytic biota, it is doubtful that subterranean mechanisms can provide substantial transport pathways for surface-water biota that lack adaptations to the groundwater environment. However, many benthic organisms are adapted to anoxia and interstitial existence (e.g. some species of rotifer, gastrotrich, harpacticoid copepod, and nematode), so the mechanism cannot be ruled out.

The sandy soil of the DLB and RRB make groundwater connections among water bodies common. The ability of organisms to disperse through groundwater is difficult to estimate, but the groundwater conditions are favorable for such dispersal, relative to regions with more clayey soils or with near-surface bedrock.

3.5.3.2 Anthropogenic Mechanisms

In addition to natural dispersal mechanisms, aquatic organisms are transported by human-mediated mechanisms that have become a focus of increasing research as such mechanisms increase in number and effectiveness, and as the effects of invasive biota have become apparent. These mechanisms are likely to be very important in the DLB and RRB, where recreational and agricultural activities are common. They include:

A. Recreational and boating-related activities.

i) Boat transport. The movement of boats, particularly those used for recreation, has been recognized as an important vector for invasive species, and can even be used to predict geographical invasion patterns (Buchan and Padilla 1999). Plants parts and small organisms, such as Eurasian watermilfoil fragments, zebra mussel larvae ("veligers"), and spiny water fleas, can easily adhere to boat trailers and be carried in bilge water and live wells without detection. It can be assumed that many indigenous species can be transported by this mechanism as well.

ii) Bait disposal. Anglers carrying bait species, and other biota inadvertently transported in bait buckets, may frequently release excess bait into waters distant from the bait source.

Because both Devils Lake and the Red River support popular commercial fisheries, and because rising water has made Devils Lake a more desirable recreational destination, boat transport and recreational activities can be assumed to be common modes of biota transport in the region, at least for certain species. Furthermore, it has been found that North Dakota residents are much less familiar with biota transport issues than are residents of some other states (e.g. Minnesota, Wisconsin) where exotic invasive species have been very problematic and have been the foci of state funds and legislation for quite some time (Grier and Sell 1999). Many recreational users of North Dakota waters come from these states, but many are local residents who are less likely to be knowledgeable about invasive species.

B. Intentional releases.

Both legally-sanctioned stocking and unauthorized release of organisms, especially fishes, into waters have been noted as important vectors of exotic species. Indigenous and naturalized species may also be introduced. These activities can transfer not only the intended species into a new water body, but also its parasites, pathogens, and inadvertent "hitchhikers". Aquarium hobbyists have been found to release more exotic fishes into local waters than was formerly believed, although many such species are not adapted to survive in the receiving waters. Another mechanism involves private citizens engaging in unauthorized game fish "stocking" and introduction of species intended as agents of biological control of unwanted plants or animals.

North Dakota waters are actively stocked by the state Game and Fish Department, and has in the past experimented with stocking some PBOC species, such as zander and grass carp (T. Steinwand, pers. comm.). The fish hatcheries in the state are certified disease-free, but the department also uses non-hatchery waters of the state as stocking sources for other waters, including those in different major drainages. Given the frequency and reciprocity of fish transfer among waters and drainages (J. Weigel, pers. comm.), it is likely that many species of fish, parasites, pathogens, and other biota accidentally captured with fish (e.g. zooplankton, algae), have been repeatedly reintroduced to waters throughout the state.

3.5.3.3 Reasons for Perceived PBOC Absence from RRB

The many existing biota transfer pathways described above suggest that it is possible for any Devils Lake species to invade the RRB, even in the absence of an outlet. If this is true, the apparent absence of PBOC species from the RRB must be explained. There are two reasons why PBOC species could, in fact, have ready access to the RRB, yet have not been detected there.

A. Sampling error and insufficient study

It is likely that many Devils Lake species already occur in the RRB but have not been detected. This is quite possible because past studies have been far too few and localized to determine that any given species is truly absent from the RRB. Relatively few waters have been studied, and these represent only a small portion of the habitat diversity present in the basin. Such a small sampling of habitats cannot convey an accurate sense of basin-wide biota richness, because local habitat differences "choose" species from among the broader, regional pool of potential occupants (Shurin et al. 2000). Species not present in the waters sampled may very well be present in other habitats. Furthermore, no habitats studied in the RRB resemble Devils Lake in both physical and chemical parameters.

Habitat characteristics in the RRB vary widely, including highly saline and alkaline waters, and water with a variety of flow conditions from stagnant to high flow (project team member observations). Rather than proposing a high level of Devils Lake endemism, it seems more reasonable to conclude that all Devils Lake species occur within the RRB, or have had frequent opportunities to become established there. Therefore, it is reasonable to conclude that these habitats have not been sufficiently investigated to assure the absence of any PBOC species from the RRB.

B. Failure to colonize

Many species may be frequently transported into RRB waters, but habitat conditions or biotic factors in the receiving systems may preclude successful colonization by these species. High dispersal rates do not always contribute significantly to local populations, either because immigrants are numerically insignificant (Boileau and Taylor 1994, Michels et al. 2001), or because local factors, such as biotic interactions and physicochemical conditions, prevent successful colonization by immigrants (Boileau and Taylor 1994, Shurin 2000). Species occurring in the DLB include those that are adapted to salinity conditions from relatively fresh to hypersaline, and to a broad array of alkalinity, sulfate, chloride, and nutrient concentrations. The habitats of the RRB are also diverse, but it is possible, though unlikely, that few or none provide the combination of physical and chemical characteristics required by some of the more halophilic Devils Lake species. The above-noted data gaps preclude any conclusions regarding this possibility.

Physical and chemical habitat parameters are crucial, but probably few if any, waters of the RRB have chemical conditions lying outside the tolerable range of Devils Lake species. If this is true, relative competitive abilities under different physicochemical conditions may be the more important factor determining community composition. Ecological theory suggests that there are superior competitors in less saline (more favorable) habitats, so the salt-adapted species, such as many Devils Lake inhabitants, aquired their adaptations by being forced into more unfavorable habitats where they are free from competitors. If individuals of these species disperse to fresher, less alkaline Red River waters, they may be unable to survive in the presence of more intense competition and predation. Thus, any future project-mediated enhancement of biota transfer would not provide a significant new invasion mechanism to these species, unless the project simultaneously disadvantages the resident superior competitors (e.g. by changing habitat parameters, as described below).

3.5.4 Potential Enhancement of Pathways Due to Project

The obvious enhancement of biota transfer pathways created by the outlet would be the direct transfer of organisms through the outlet itself. According to the present design, the outlet intake apparatus would consist of a pump platform with intakes suspended approximately 13 feet below the water surface. The intake openings would be covered with stainless steel screens to prevent fish and large debris entering the pumps. Organisms most likely to be transferred in substantial numbers by such a design would include planktonic algae, copepods, cladocera, rotifers, protozoa, and larval fish. The Peterson Coulee design locates the intakes in a channel leading from West Bay toward the watershed divide, in shallow water away from the deeper, open waters of the lake. This would make transfer of littoral organisms most likely, while pelagic (open water) plankton would be much less likely to occur in such a protected area. However, operation of the pumps would create a flow down the channel toward the intakes, so some pelagic organisms may be drawn into the sheltered habitat of the channel. Depending on the strength of the flow, benthic organisms may also be dislodged from the channel bottom and carried into the intake, but this would only be expected to occur in the pump channel. Organisms least likely to be transferred by the pump would be fishes that spend all life stages in deeper water, truly pelagic plankton, most benthic organisms, and, especially, those halophilic organisms that are largely confined to the remaining few sub-saline areas in the eastern portions of the lake.

Natural pathways for transfer of biota from Devils Lake to the RRB involve climatological phenomena and movements of animals. Neither of these factors is likely to be significantly affected by the project, with one exception. If the sustained summer-long high flows in the Sheyenne River attract mammals, birds, or reptiles, then the likelihood of biota transfer would increase proportionally to the increase in vertebrate animal traffic from the DLB to the Sheyenne River. Also the fact that the pumped water will move via pipes suggests that the outlet corridor itself will not be rendered more attractive to non-avian vertebrate traffic. Whether any such increases would occur or be significant is impossible to determine. Literature review revealed little related scientific information on the frequency of vertebrate-mediated transmission of aquatic biota between basins, and data on movements of vertebrates in the Devils Lake region were not available, so estimation of the effectiveness of this transfer pathway were not attempted.

Anthropogenic biota transfer between the DLB and the RRB is probably dominated by recreational boaters travelling across the basin divide. The importation of non-native species into Devils Lake from non-Red-River basins has been noted as an area of concern. Because Devils Lake is an attractive recreation destination for tourists from many states, the lake could serve as a collection point for invasive species that could be transmitted to the RRB through the proposed outlet. This pathway from other basins to Devils Lake has probably increased recently, as rising Devils Lake water levels have increased fish production, making the lake more attractive to anglers. It is unlikely that the outlet project would further enhance this pathway because, if anything, it will lower the lake level, beginning a reversal of the trend that made the lake more attractive for anglers. However, as in the case of present residents of the lake, species that are introduced into Devils Lake from distant basins could be susceptible to an increased likelihood of transfer to the Red River if the outlet is constructed.

Another concern is that the project could possibly increase the recreational use of the Sheyenne River by sustaining high flows throughout the summer season, thus increasing the river's usefulness to canoists and anglers. By increasing the volume of recreational users on the Sheyenne over longer portions of the year, the likelihood of biota transfer would increase as a simple function of the increased annual number of person-visits to the river. Of course, biota transfer from the DLB could only occur if the person had recently visited DLB waters and a means of transport was provided. Neither present use statistics nor future projections were available, so estimates of the effectiveness of this transfer pathway were not possible.

3.5.5 Effects of Downstream Habitat Changes on Possible Invasiveness of PBOC

The problem of biota transfer into the RRB does not simply involve the possibility of a Devils Lake outlet transporting "new" species into the Sheyenne River; it also involves habitat changes that may favor the establishment of populations of these species in the RRB. Habitat changes are expected to be very subtle or even absent once Sheyenne River water is diluted by its discharge into the Red River near Fargo. Accordingly, this study focused on likely effects of the project on Sheyenne River habitats.

Adverse impacts to Sheyenne River communities can be expected, but the extent to which these impacts involve biota transfer from Devils Lake is less certain. Many possible habitat changes could favor certain invasive species, while other changes could provide disadvantages; effects could be the opposite for other invasive species. The possible effects discussed below were based on well-studied phenomena in stream systems, but the effects of a combination of factors cannot be predicted. In general, a cautious approach suggests that any disadvantage to existing Sheyenne River biota offers opportunities for invasive species to become established. On the other hand, biota introduced to the Sheyenne River from Devils Lake would generally be lentic species, not particularly adapted to lotic conditions. Even species that appear to be habitat generalists may occur in Devils Lake as lentic-adapted ecotypes, so their ability to easily invade a river system should not be assumed. Invasive species from Devils Lake would be most likely to become established in Lake Ashtabula, slow-moving pools along the Sheyenne and Red Rivers, and perhaps Lake Winnipeg.

Despite differences in lotic and lentic systems, an outlet could provide a constant source of immigrants that could cause problems downstream. While a species may not be able to gain a substantial foothold in the Sheyenne River based on small-scale immigration, a constant influx of individuals could overwhelm the habitat disadvantages, thus allowing the species to become effectively established in the river, at least while the outlet is in operation. One example of such a case would be the transfer of planktonic algae into the river. Such algal species would probably not last long in the river if only introduced once. They may find temporary refuge in pools and backwaters, but periodic high flows would eventually flush them downstream. However, a constant influx of these species from a Devils Lake outlet could continually replace those individuals previously flushed out.

3.5.5.1 Increased Volume & Duration of Flows

The proposed outlet would run during seven months of the year, increasing flow volume and stage height in the Sheyenne River. Increasing flow in streams can alter many physical habitat factors which can have subsequent effects on chemical and biological characteristics of the system. In fact, flow rate, through many cascading effects, is probably the single most influential environmental factor determining the character of lotic systems and the composition of stream communities. The physical characteristics likely to be affected are summarized below.

The most direct biota transfer effects of increasing flow volume are the increased numbers, sizes and transport rates of organisms being moved downstream. The cautious approach is to assume that any invasive species occurring in the Sheyenne River, whether originating in Devils Lake or elsewhere, would be more likely to move downstream during outlet operation, and to possibly do so faster, than under a no-outlet scenario. Many factors would interact to determine transport rates of various species. One such factor is the effect of Lake Ashtabula as a partial barrier that slows flow and allows organisms to sink from suspension and find habitats in which to become established. However, once established, the new populations would likely serve as sources of new emigrants to downstream regions.

The phenomena of downstream drift and organisms' passive and active responses to increased flow have been well-studied (Allan 1995), but more detailed study would be required to determine which species would be moved downstream faster under higher-flow conditions in the Sheyenne River. Some fish and invertebrate species are negatively rheotactic, increasing their upstream movements in response to increased downstream flow, while others find refuge in deep sediments in direct response to increased flow. Most lotic-adapted species of plants, algae and invertebrates become attached to stream substrates, so increased flow may not move them downstream. Even if portions of plants break off, invertebrates are dislodged, or epilithic algae are sloughed under high flow, Lake Ashtabula would act as a break in the high-flow continuum, so effects further downstream would be determined by the timing and technique of water release through Baldhill Dam.

The recent observations of Eurasian watermilfoil in the Sheyenne River (B. Alexander, pers. comm.) has been a concern because of the species' prolific growth rates and ability to regenerate from small fragments. Under present conditions, downstream transfer appears inevitable, but an outlet could potentially speed the process by increasing flows. However, it is possible that present risk of transfer is relatively small because there are relatively unsuitable habitats for the species in the Sheyenne/Red River system. In such a case, the outlet would be of even greater concern because it could increase the species' ability to invade suitable habitats further downstream, "skipping over" less suitable intervening reaches. On the other hand, higher flows could also result in the species skipping over otherwise suitable habitat areas as well. Similar arguments may be applicable to other exotic species in the Sheyenne/Red system, but intricate analysis of such phenomena fall outside the scope of the present study, unless the species in question are presently found in Devils Lake. Given the fact that Eurasian watermilfoil is already in the Sheyenne River, it is virtually certain to move downstream and invade suitable habitats, with or without a Devils Lake outlet.

An additional concern related directly to flow regime alteration is the possibility that species currently inhabiting the Sheyenne River may depend on the present seasonal cycle in flow rates. Some species may require a period of low-flow during the growing season to mate or spawn, or for the more gentle habitat conditions that may favor juveniles not yet adapted to high-flow conditions. Such effects on existing Sheyenne River biota is beyond this study's scope, but it should be considered that any disadvantage to or weakening of existing communities in the Sheyenne River could provide opportunities for invading species to exploit niches and compete successfully with resident species. However, these possibilities are speculative, and would required further study to be fully understood.

3.5.5.2 Erosion, Sedimentation and Changes to Stream Morphology

Increasing stream flow increases streambank erosion, so bank slopes become steeper and less stable. This can thin or eliminate much channel-margin and riparian vegetation while adding large quantities of sediment to the water column. Such sediment additions cause many problems, including local alteration of benthic habitats, and turbidity problems that extend downstream. Turbidity blocks photosynthetically-active radiation from anchored and sediment-attached primary producers. This generally reduces overall primary productivity because, unlike lakes, lotic habitats don't generally support dense phytoplankton communities to compensate for macrophyte and benthic algae losses. Higher turbidity also reduces foraging efficiency in visually feeding animals, particularly fishes. Such animals leave the immediately affected area, seeking more favorable hunting grounds, and "rough" fish, such as carp and bullheads, take advantage of the vacated habitats.

Flow determines substrate type in streams, so changing flow changes the character of stream bottoms. As flow increases, the scouring force of the water increases, so progressively larger grades of substrate particles are dislodged and moved downstream. The smallest and most easily moved particles are fine-textured clay; slightly higher flows can move the next size class, "silt". As flow rate increases, increasingly large particles, such as sand, gravel, cobble and ultimately, boulder size classes are eroded. As a result, the higher the flow in a lotic system, the larger will be the mean particle size found on its bottom. Changes in stream bottom characteristics tend to shift stream biota in predictable ways, but until the new conditions stabilize, the changes can be erratic and destructive to existing communities.

Because erosion dislodges substrate and streambank particles, increased erosion increases sediment loads which can be transported considerable distances downstream. In fact, higher flow rates should also increase sediment transport distances by reducing slow "pool" reaches where sediments can settle out of the water column. As particles move downstream, they can create harsh conditions for many organisms. Suspended particles can abrade plants and invertebrates, creating a subtle "sand blasting" type of effect that only armored organisms can withstand for long without seeking shelter. Larger particles such as coarse sand, gravel, and larger rocks can be destructive as they are pushed along the substrate in a saltatorial manner, repeatedly striking the stream bottom.

Sediment that settles out of the water column in slower areas of channels can cover macrophyte leaves and benthic algae, and can occlude the gills of fishes and, especially the more delicate gill-bearing benthic invertebrates, such as mayfly nymphs and mussels. Settling sediment also has the opposite effect of eroding sediments: streambeds become more sand, silt, and clay-laden in slow-flow reaches. This can reduce intra-substrate (hyporheic) flow, creating a hypoxic-to-anoxic benthic environment.

By increasing the magnitude of streambank erosion and deposition processes, stream flow increases can accelerate stream meandering in unconstrained channels. This increases habitat vagility, which can create a less benign habitat for many species, though it can also increase habitat diversity in some respects.

3.5.5.3 Water Chemistry Changes

Water chemistry affects biota in various ways, depending on the type of organism. Many aspects of water chemistry are important to biota, but the two primary concerns that could result from the operation of a Devils Lake outlet are salinity increases and nutrient enrichment.

A. Salinity increases

Salinity (the total concentration of ions) affects biota primarily through osmotic pressure, which is determined by the internal/external difference in ion concentration across the cell membranes of the organism's body wall. Diffusive forces cause molecules to "attempt" to equalize concentrations by moving in the direction of lesser concentration. However, because dissolved ions cannot move across cell membranes, water molecules move in the opposite direction to compensate. In other words, when environmental ion concentration is higher than intracellular concentration, water passes out of the organism to the region of higher ion/lower water concentration. Thus, high salinity, relative to intracellular concentrations, causes organisms to lose water, and increasing salinity causes this water loss to accelerate, unless the organism can compensate. Of course, low relative salinity causes organisms to absorb water.

Excessive water loss or gain is detrimental to organisms, so each species shows "preference" for a given salinity range by regulating internal ion concentration (osmoregulating) through combinations of anatomical, physiological, and behavioral adaptations. When species suddenly find themselves at either extreme of their preferred range, stress occurs, forcing the organism to use more and more energy to osmoregulate. If environmental conditions are outside the organism's range, it will die. Stress and death of individuals weakens the competetive ability of a population, thus allowing other species with better adaptations for present conditions to invade their niche.

Stewart and Kantrud (1972) created a salinity scale for surface waters in the prairie region, which can be used to compare the waters discussed in this study. Devils Lake has higher salinity than Sheyenne and Red River waters. A broad range of salinity conditions occur in Devils Lake, with a general west-to-east trend of increasing salinity from "slightly brackish" West Bay water (specific conductance 500-2,000 μmhos/cm @ 25ºC) with ~1140 mg/L Total Dissolved Solids (TDS), to "brackish" Wast Devils Lake (5,000-15,000 μmhos/cm) with ~5450 mg/L TDS (all salinity categories with conductivities *sensu* Stewart and Kantrud 1972, TDS data from Wiche 1998). Stump Lake, to the east of Devils Lake, has the highest concentrations of total dissolved solids, being classified as "saline" (45,000-100,000 μmhos/cm) when lake levels were low, but under the present diluted conditions, conductance is down to 11,600 μmhos/cm. The least-saline water occurs in the "slightly brackish" West Bay of Devils Lake, and especially in the northern lakes that drain into Devils Lake. These lakes have similar salinity levels to those found in the Sheyenne River, which fluctuates between "fresh" and the low end of the "slightly brackish" range, with an average TDS ~480 mg/L (Wiche et al. 2000).

At present, outlet plans call for drawing water from West Bay through Peterson Coulee, or from Pelican Lake to the north. Under these scenarios, Sheyenne River water would experience increased TDS and sulfate concentrations, with a near doubling of these measures under the Peterson Coulee outlet plan (Wiche et al. 2000), and smaller increases under the Pelican Lake plan. Salinity increases would be most apparent just below the outlet, and would diminish further downstream as natural inflows dilute the water. Salinity would drop further where the Sheyenne River meets the Red River, and significant downstream dilution could bring salinity down to normal levels upstream of the Canadian border. In the most extreme salinity-increase scenario, the No Action (natural spill) Alternative could raise Sheyenne River salinity by an order of magnitude below the outlet discharge. Substantial, though progressively decreasing, salinity levels would be seen downstream as far as Grand Forks, but low-salinity inputs below this point would result in greatly diminished effects at the Canadian border (Barr Engineering 1999).

Quantitative, though probabilistic, forecasts have been calculated to project salinity increases under different scenarios, but they are not useful in this study because salinity responses and other chemical preferences of PBOC species are poorly known. At best, some species are noted in the literature as occurring in "fresh", "brackish", "saline", or "marine" conditions, with no clear definitions of these terms. Even this level of information is of little use in the present study because: 1) many of the freshest waters in North Dakota, such as the Sheyenne River, have relatively high salinities; 2) "brackish", used colloquially, includes a broad range of salinities, the entiret continuum of which is represented within the DLB and RRB; and 3) projected salinity increases from the outlet project would only elevate Sheyenne River salinity to "slightly brackish" (*sensu* Stewart and Kantrud 1972), which is probably within the tolerance ranges of most species present in North Dakota.

Projections indicate that the outlet project would not raise Sheyenne River salinity to very high levels, but percentage increases could be quite high. Salinity increases could create subtle habitat shifts that favor halophilic (adapted to elevated salinity) species over more halophobic (confined to "freshwater" salinity levels) species. Halophiles are fairly common in Devils Lake, so they could be transferred to the Sheyenne River and find favorable habitat under higher-salinity conditions. In such a case, it is likely that the relative abundances of halophilic species would increase during outlet operation, but the effect would probably be reversed when the outlet is no longer in operation.

B. Nutrient enrichment

The effects of changes in nutrient concentrations can be very complex and are impossible to predict reliably in any system that has not been extensively studied. Dissolved nutrient concentrations are very important determinants of bacterial and algal population growth and community dominance. In general, more nutrients mean more rapid growth and reproduction of microbes at the base of the food web, but other factors can limit growth even if nutrients increase. It is not possible to predict growth increases resulting from nutrient increases for any given system without prior research to determine which factors most limit growth. However, non-marine aquatic systems are most-commonly limited by phosphorus or nitrogen, though this can change with seasonal conditions. In most systems, pulses of phosphorus or nitrogen stimulate algal growth, with effects often cascading up the food web in the form of increased growth and/or reproduction at higher trophic levels, at least initially.

The two nutrient-enrichment effects of greatest concern in this study are eutrophication and Cyanobacteria dominance. Eutrophication is a result of high nutrient loading that stimulates rapid algal growth. High algal production results in, among other things, large numbers of dead and dying algal cells. Decomposition of these cells by bacteria consumes oxygen and entire water bodies can become oxygen depleted, posing serious dangers to all oxygen-dependent aquatic organisms. In some cases, phosphorus loading is high enough to cause nitrogen to be the limiting nutrient. This often leads to the dominance of algal communities by Cyanobacteria ("blue-green algae") that are rare among all biota in having the capacity to obtain nitrogen from the almost-limitless pool of atmospheric gaseous nitrogen. Blue-green algae present two problems: they are inedible to most aquatic algae grazers and some species actually produce toxins. These toxins can be very potent, and can occur in high concentrations when toxin-producing species bloom under ideal growth conditions.

There has been some concern that introducing Devils Lake water into the Sheyenne River could enhance system productivity downstream from the outlet (e.g. Phillips et al 2000, USACE 1996), moving the system toward a eutrophic state. However, neither fully comparable nutrient data from potential source and receiving waters, nor modelling of future nutrient changes in the Sheyenne River, were available for this study. Nonetheless, existing data allowed some preliminary assessments of the likely effects based on pre-outlet nutrient concentration differences between water bodies.

Recent nutrient data were collected from Devils Lake from 1995 to 1999 by Elstad (1999) . Fairly comparable data were collected from several locations on the Sheyenne River in 1997 and 1998 by Phillips et al. (2000). Comparing these data shows that dissolved phosphorus levels in the western parts of Devils Lake are very similar to those found in the Sheyenne River near the proposed outlet. In 1997, Devils Lake water in the west Minnewaukan flats region ranged from ~0.2 to ~0.3 mg/L mean total phosphorus (July to October), as compared to the ~0.219 mg/L (measured as orthophosphate, September to October mean) average for two sites on the Sheyenne River: near Maddock and near Warwick. Comparisons of 1998 data reveal similar results, although phosphorus values were higher in both water bodies that year.

In contrast, nitrogen concentrations differed substantially between the water bodies, with the Sheyenne River carrying higher loads of nitrate+nitrite than Devils Lake, but with Devils Lake probably carrying much higher total nitrogen concentrations. Devils Lake nitrate+nitrite ranged from 0.02 to 0.16 mg/L in September and October of 1997; Sheyenne River nitrate+nitrite averaged 0.168 mg/L for the same period, with 0.082 mg/L at Maddock increasing to 0.254 mg/L at Warwick. (The proposed outlet would discharge into the main stem of the river between these sites.) These values represent only a fraction of total nitrogen, but no other nitrogen data were available from the Sheyenne River for this study. Devils Lake has quite high levels of organic nitrogen (according to data in Elstad 1999), as does Lake Ashtabula (Phillips et al. 2000), which probably is a result of high nitrogen fixation by Cyanobacteria. It is reasonable to expect lower organic nitrogen in the Sheyenne River because it does not support the abundance of these algae that are found in the lakes. Similarly, Devils Lake may have higher levels of ammonium nitrogen than the river because its stagnant waters provide anaerobic benthic substrates that produce the chemically reduced nitrogen compound. If nitrate+nitrite is assumed to approximate total nitrogen for the river, as it well might, then nitrogen loads in Devils Lake water greatly exceed Sheyenne River loads. Total nitrogen for Devils Lake in September-October, 1997 ranged from 1.31 to 2.04 mg/L, an order of magnitude greater than nitrate+nitrite concentrations in the Sheyenne River for the same time. Elstad (1999) did not provide nitrogen data from 1998, but the 1999 values were very similar to those from 1997.

Devils Lake is generally considered eutrophic-to-hypereutrophic, but quantitative comparisons of Devils Lake with nearby waters were not found for this study. More eutrophication-related studies were found for Lake Ashtabula than for the Sheyenne or Red Rivers. Taylor et al. (1979b) evaluated the trophic status of several North Dakota lakes using two independent algae-based index systems and a set of standard diversity-related measures. They applied five Nygaard Trophic State Indices, including a composite index, to algae data collected on three sampling dates (in May, July, and September) in 1974. The composite index indicated a substantially higher state of eutrophy in Lake Ashtabula than in Devils Lake. Differences in the sub-indices varied in magnitude, but generally also showed greater eutrophication in Lake Ashtabula. Each index showed the reverse or no difference on one date only. Similarly, Palmer's Organic Pollution Indices gave a higher eutrophy rating to Lake Ashtabula, though these indices are not independent of the total species number used in its calulation. This means that the lower species richness in Devils Lake can cause low ratings of eutrophy, despite the fact that salinity was probably the reason for the richness differences between the two lakes. More interesting is the fact that, despite lower species richness, Devils Lake had higher average Shannon diversity on two of three dates, largely because community evenness was higher than in Lake Ashtabula.

Devils Lake has an especially species-rich and dense community of Cyanobacteria, including some toxin-producing species that are apparently not present in the Sheyenne/Red River system, (though it is likely that they are present but undetected in some waters of the RRB). An influx of nutrient-rich water to the Sheyenne River could create conditions that would favor the growth of these blue-green algae, and other eutrophication indicator species. However, the inflowing water from Devils Lake would be nitrogen-rich, whereas Cyanobacteria are usually favored in nitrogen-limited (low N:P) environments, so green algae may have a greater advantage. It is difficult to predict which algae would increase in number, but the inflow of both phosphorus and nitrogen would almost certainly stimulate algal productivity in the river.

Lake Ashtabula is already very eutrophic, even compared to Devils Lake, so increased nutrient concentrations in Sheyenne River water could, in fact, lower nutrient concentrations in the lake. Under the elevated-nitrogen scenario created by the outlet, algal community changes would likely occur, as well as resulting changes in both absolute and relative nutrient uptake rates. Therefore it is difficult to predict how much phosphorus and nitrogen would stay in suspension by the time Sheyenne River water reaches Lake Ashtabula, but if these two nutrients remain in suspension in somewhat similar proportions as at the outlet, the relatively higher nitrogen levels (higher N:P) could stimulate green algae more than Cyanobacteria, which would probably be seen as a desirable outcome, at least from an aesthetic perspective.

3.5.6 Potential Effects of Downstream Habitat Changes on PBOC

Changes in habitat such as those described above can have many interacting and cascading effects on biota. These changes cannot be predicted with great specificity, but some general statements can be made by first summarizing the expected habitat change, and then considering how each type of PBOC species would respond to such a habitat if introduced.

The upper Sheyenne River, above Lake Ashatabula, would remain a lotic system, but would experience higher stages and flow rates for nearly the entire growing season. Waters would be more turbid and benthic substrates would have larger mean particle sizes in fast areas, but would probably have lower mean particle sizes in slow areas, where the eroded particles could settle to the bottom. Water chemistry would change, having higher TDS, sulfate, and nitrogen-compound concentrations. The shallow and rocky "riffle" habitats would probably be lost throughout the periods of outlet operation, giving way to deeper "run" habitats.

Lake Ashtabula would not change physically to any great extent, except that basin retention time would necessarily shorten because higher inflow volume would require more frequent and/or voluminous releases through Baldhill Dam. These changes would probably not change biological communities appreciably, although increased water release into the lower Sheyenne River would increase the frequency of biota export from Lake Ashtabula.

The chemical composition of Lake Ashtabula would change somewhat. Salinity, both TDS and sulfate, would increase in Lake Ashtabula. Total nutrient concentration changes would probably be negligible, but inflows from the Sheyenne River may have higher N:P than occur without the outlet.

3.5.6.1 Changes in Relative Abundance

PBOC species invading the Sheyenne River and Lake Ashtabula would be confronted with habitats that range from very different to only slightly different from the Devils Lake habitats they emigrated from. It is likely that many of these species are physiologically plastic enough to adapt to the chemical environments they would encounter, but fewer species would be anatomically and behaviorally adapted to high-flow environments. This suggests that, while many species may become transient residents of the Sheyenne River, they are more likely to become established, reproducing populations in Lake Ashtabula.

In Lake Ashtabula, it is very unlikely that any physical or chemical characteristics would exclude any PBOC species. Chemical changes in the Lake would be relatively small, but could affect the competetive abilities of many species. The ultimate determinants of which species become established and increase in relative abundance would be the unpredictable biotic interactions that would occur among all native and invading species. Those most likely to be favored are those already adapted to moderately higher salinity.

The PBOC species most likely to invade and competetively dominate Lake Ashtabula habitats are the halophilic algae, such as the Cyanobacteria species discussed in detail below. These planktonic algae would not find much colonizable habitat in the Sheyenne River, but they could take advantage of elevated salinity in Lake Ashtabula to gain a foothold among native species that may be stressed by higher TDS. The potentially changing nutrient balance in the lake may favor invasive Chlorophyta over Cyanobacteria, but it would not prohibit the establishment of invasive Cyanobacteria at low to moderate concentrations in the plankton. Once established, the Cyanobacteria in particular may pose a nuisance-bloom threat in the future.

Of the remaining PBOC species, few are known halophiles, but specific habitat preferences and tolerances are little known for most. All PBOC zooplankton species (Copepoda, Cladocera, Rotifera) would find the lotic habitats of the Sheyenne River challenging, but could become established in Lake Ashtabula, especially if higher salinity creates disadvantages for rival native species. However, it is highly likely that these species already exist in the lake or have had opportunities to colonize it, but were not very successful due to native competition and predation. The same can be said for the other PBOC invertebrates, which are little-studied and whose presence or absence in downstream habitats has not been convincingly determined.

A list of species likely to be directly enhanced or harmed by changing chemical conditions cannot be produced because species' preferred habitat parameter ranges are so little known and so vaguely defined. Further, multiple species that are well-adapted to the chemical changes may interact (through competition, predation, parasitism, mutualism, etc.), producing a community that could not be predicted. The state of scientific knowledge about competetive and other interactive effects does not extend to the ability to predict outcomes of competetive events between particular species. In addition, many PBOC species are probably generalist, without very specific habitat requirements. Chemically sensitive, adapted, and generalist species occur in all major biota groups addressed in this study, but Cyanobacteria are one group that would likely be favored by the habitat changes predicted in Lake Ashtabula, and possibly as far as the Red River mainstem and even Lake Winnipeg.

3.5.6.2 Changes in Range

If the PBOC species truly are absent from the RRB, then any species newly introduced to the river that becomes established could represent a range expansion. Patalas et al. (1994) provided distribution maps for crustacean zooplankton of Canada. Table 11 summarizes this information, which suggested that two zooplankton PBOC species could extend their ranges into Lake Winnipeg via the proposed outlet. However, the maps' resolution level was too low to determine this definitively, and they did not include the U.S., so whether these species' ranges bordered or overlapped the RRB could not be determined.

For many PBOC species, geographic distribution information was too vague to determine whether Devils Lake lies at or beyond the known edge of their ranges. For the remaining PBOC species, the RRB was found to lie within their known range, so it is unlikely that these species have not already been repeatedly introduced into the basin, whether they were successful colonizers or not. However, because introduction to the Sheyenne River could theoretically result in the species being carried as far as Hudson's Bay, the possibilities of range expansions should not be completely dismissed.

3.5.6.3 Changes in Invasive Potential

The invasive potential of species noted in this study is difficult to assess. There is no commonly accepted quantitative or qualitative "invasiveness" parameter, and the concept of invasive potential has only recently been widely discussed. Certain known aggressive exotic species are considered highly invasive, but none of these species are known to occur in Devils Lake. Thus, a simpler definition of invasiveness is best applied here. Any species that finds favorable physical and chemical conditions in a newly invaded habitat, and is able to withstand the pressures of local competition, predation, and parasitism, may become invasive. These conditions combined with a high reproductive potential could combine to produce a highly invasive species. Based on these criteria, no PBOC species in this study would be precluded from being invasive, because invasiveness is case-specific, depending on the habitat in question and the abilities of the species relative to co-occurring species. Literature searches have revealed that, as noted above, too little is known of species' habitat needs and responses to other inhabitants to predict invasiveness of listed PBOC.

3.5.7 Potential for Regulating Pathways

Naturally occurring pathways for biota transfer are numerous and diffuse, so they cannot feasibly be controlled by human-created mechanisms. Anthropogenic pathways, however, can be controlled to some extent. The greatest possibility of government influence over existing pathways probably exists in attempts to reduce human-caused dispersal by educating recreational boaters and anglers about their potential role in creating pathways across the basin divides. Education of boaters has been effective in some states, such as Minnesota and Wisconsin, but at present North Dakota residents are much less informed about their potential roles in the spread of exotic invasive species (Grier and Sell 1999). A broad public education campaign could reduce the occurrences of species transmission by boats and by unauthorized releases, if the public is convinced that exotic species pose tangible threats.

3.6 SELECTION OF BIOTA FOR RISK ASSESSMENT

3.6.1 BRA Selection Process

The task of selection of species for further analysis was complicated by the many data gaps noted above. These gaps frequently precluded definitive answers to questions in the decision tree listed in Section 2.0. Accordingly, several species and biota groups received special scrutiny to determine whether they were of sufficient concern to warrant a full risk assessment.

Taxa that were definitively rejected as BRA are listed in Table 12 which includes a summary of the reasons for their rejection. Those not initially rejected were considered "Provisional" BRA species, consisting of species that were not deemed problematic if transferred to the Red River system unless simultaneous habitat changes would favor their becoming competetive dominants. These could include species with populations presently found in downstream habitats that could be enhanced by new influxes of individuals of the same species. Many such species could appear to become invasive because of the projected water chemistry changes caused by the inflow of Devils Lake water into the Sheyenne River. Of these species, those not recorded from downstream habitats are believed to already have access to the Sheyenne River through existing dispersal routes, based on existing literature on the species' dispersal abilities. It is very likely that many of them not only have access, but have already established populations within the RRB in habitats that have merely been overlooked by researchers.

Any species that already occur in, or have dispersal pathways into, the RRB would not truly be biota "transferred" by the outlet. Even if the outlet is built and brings many more individuals of the species into the Sheyenne River, it is ultimately the habitat changes that will have caused the apparent "invasion", while the influx of new individuals would probably be relatively unimportant. For these reasons, these "provisional" species were examined further, but ultimately not carried on to the BRA stage. Effects of outlet-created habitat changes on species already existing in the RRB are not a study focus dictated by the Statement of Work for this project. However, because it has not been proven that these species are present in the RRB, attempts were made to identify those species that could become, or could appear to become, invasive and problematic, as a result of outlet-induced habitat changes in the Sheyenne River.

Most of the above-described "provisional" species were not deemed overtly hazardous, but were investigated more thoroughly because initial research revealed that they had caused distinct biological, ecological, or economic problems in other places. However, in each case, further investigation of the species provided information that either dispelled previous concerns, or provided reasons to consider potential harm in the RRB to be very unlikely.

Finally, two species were elevated to the level of full Biota for Risk Analysis: Eurasian watermilfoil (*Myriophyllum spicatum*) and striped bass (*Morone saxatilis*). These were selected for risk analysis because they are both non-natives known to occur, or to have occurred, in waters that would certainly be affected by an outlet or natural overflow from Devils Lake, and because both are known to affect communities that they invade.

3.6.2 Non-BRA Species

The large majority of PBOC were ultimately classified as "Non-BRA" species. They were found to be widespread in distribution, and/or able to disperse readily among water bodies. In fact, it seems highly unlikely that many of the species known from Devils Lake have not had access to the RRB periodically since its last natural spill into the Sheyenne River. While biologists have not fully determined all means of overland dispersal used by aquatic organisms, the fact that it occurs is not in dispute. The occurrence of the same species among waters over very large areas shows that natural dispersal mechanisms are quite effective. Most aquatic organisms within a region manage to "find" their appropriate habitats, even if they are isolated stream headwaters, temporary ponds, or water-filled tree-holes, plant "cups", or other similarly small and dispersed habitats.

The Non-BRA were also found to have no history of being particularly invasive or of causing human-defined problems in their usual habitats. It is impossible to predict the effects of any species' new introduction to a system, as the history of past exotic species introductions clearly shows. It is especially difficult to predict any of the subtle community changes that can result from a new and capable competitor being introduced, however, the purpose of this study was to determine likely effects of an outlet project based on existing information, and the existing information suggests that the species classified as Non-BRA are likely to be benign in the RRB.

All but two automatically listed species were classified as Non-BRA because they have not been reported as occurring in the Devils Lake basin. In fact, several of these species are known to occur in the Red River basin already. Several diseases of fish, including the striped bass diseases collectively, were automatically listed. No record of these diseases occurring in Devils Lake were found, and a pathogen screening study is presently under way, so no further analysis of fish diseases was carried out.

All protozoa and invertebrates and most algae PBOC taxa were rejected from BRA classification because: 1) scientific literature indicates a high probability that these species already have access to the RRB through known and presumed dispersal mechanisms, and 2) these taxa have been shown to cause problems in other systems.

Most microbial and meiofaunal species are widespread, continentally distributed, or even globally cosmopolitan. Dispersal mechanisms are not definitively known for all taxa, but the fact of their widespread occurrence is obvious. However, recent research suggests that "cosmopolitan" species frequently are not single species, but are assemblages of sister species with regional adaptations (Frey 1982). This indicates greater local adaptation, hence less cosmopolitanism, than previously believed, but these findings do not affect the results described here because the very short distances and low elevations of landforms between waters of the DLB and RRB are assumed to preclude allopatric speciation by allowing frequent reciprocal dispersal by passive means. Only where imposing barriers (e.g. mountain ranges, oceans, latitudinal climatic shifts) preclude gene flow can isolated populations (or metapopulations) diverge and speciate.

Specific reasons for the deselection of most species/taxa from the list of species warranting further analysis are summarized below:

a. Most algae PBOC were deselected because all were considered to have widespread distribution, existing pathways to the RRB, and a high likelihood that they have had frequent opportunities to invade RRB habitats. Those algae with more specific habitat affinities (e.g. brackish-water species) are likely to already occur in specialized habitats within the basin, and further field studies would likely confirm this. However, because of the known hazards associated with certain nuisance species, a few algae were not deselected from the list initially. These are discussed in detail below.

b. Other than Eurasian watermilfoil, all vascular plant PBOC were deselected because they have not been reported from the Devils Lake basin.

c. Other than striped bass, all fish species were deselected because they have not been reported from the Devils Lake basin (all were automatic PBOC).

d. All invertebrate PBOC were deselected. Most were considered to have existing pathways for passive overland dispersal and a high likelihood of occurring in the basin. These included Copepoda, Cladocera, Rotifera, and Gastrotricha. PBOC Nematoda were considered to also have active mechanisms of overland dispersal because they are not obligate aquatic organisms, but can thrive in moist soil habitats also. The Conchostraca and Anostraca (*Artemia salina*) were considered to have passive modes of dispersal, and also to be less likely than most to find favorable habitats in the RRB, except for ephemeral ponds or saline waters (for *A. salina*). Literature suggests that the flatworm species, *Gyratrix hermaphroditus*, may have less effective modes of passive dispersal, but it has probably had ample opportunity to invade the RRB because of the short distances between waters of the two basins and because it is likely to be able to live in moist soil habitats. Even if this species does not occur in the RRB, no evidence was found to suggest that it ever has or will cause any problems in new habitats.

e. The three fish parasite PBOC species were analyzed further because of their known capacity to harm fisheries. However, these were also considered to probably have effective existing pathways to the RRB. These species are discussed further below.

f. Avian botulism was deselected from the list because it is a widespread disease that occurs in many locations in the Lake Winnipeg basin and RRB.

3.6.3 Parasites of Fishes

Fish parasites were a particular concern noted in the Statement of Work, so additional attention was paid to this topic. This was difficult because the literature on parasite fauna of the DLB is almost nonexistent. Only Reinisch (1981) studied Devils Lake fish parasites; while other lakes in the basin have not been studied. Three parasite species were recorded. In the published literature we found three parasite species recorded in Devils Lake that had not been reported in the RRB or Lake Winnipeg. Further information was sought from experts and the biology of these species was explored in more detail. Based on these efforts, none of these species was carried forward as BRA species, for the specific reasons described below.

Ligula intestinalis:

This fish tapeworm was one of three parasite species recorded in the published literature as occurring in Devils Lake but not in other waters of the Red River drainage. However, as noted in the biological description provided previously, this species is not host-specific and is widespread, being dispersed by birds, its definitive host. Regional parasite experts have confirmed its presence in much of the Hudson's Bay drainage, and have stated that it is highly unlikely that the species is confined only to Devils Lake in North Dakota (T. Dick, H. Holloway, J. Marcino, pers.comm). Accordingly, the species was not analyzed any further.

Gyrodactylus hoffmani:

This parasite was investigated more thoroughly because it was one of the three fish parasite species recorded from Devils Lake but not from the RRB. *G. hoffmani* is a parasite of a fish species (fathead minnow, *Pimephales promelas*) commonly used as prey by game fishes, so it could be of concern to those with economic interests in RRB fisheries. The fathead minnow is also a commonly used baitfish. Holloway (1986) noted that another worker found the species in Cottonwood Lake, McHenry County, North Dakota, which is in the Souris River sub-basin of the Hudson's Bay drainage.

After a literature search for distribution records and biological profiles of the species proved revealed no specific records of the parasite in the RRB or Lake Winnipeg, evidence of its presence in the Minnesota portion of the RRB became available through expert consultation. J. Marcino, fish pathologist at the MN Department of Natural Resources, expressed certainty that *G. hoffmani* occurs throughout Minnesota, including in the waters of the RRB (pers. comm.). T. Dick of the University of Manitoba was not aware of the species being present in the province, but he noted that members of the genus *Gyrodactylus* tend to be host-specific, and because he has rarely studied parasites of minnows, *G. hoffmani* could be present but undetected in the Canadian portion of the RRB. The fathead minnow is naturally one of the most widely-distributed fish species, occurring in a wide variety of waters including isolated temporary ponds. Its distribution has undoubtedly also been expanded through its common use as baitfish by anglers. Its natural means of overland dispersal are not well known, but its effectiveness in colonizing habitats may be higher than any other fish species in the region. The fathead minnow and its parasites are thought to have access to all waters of the Red River system, so upstream and downstream dispersal from Minnesota portions of the system can be assumed with high degree of confidence. Based on expert opinions and the ubiquity of fathead minnows, further analysis of *G. hoffmani* was not undertaken.

Rhadinorhyncus sp.:

Reinisch (1981) identified an intestinal parasite of Devils's Lake walleye, yellow perch and white bass as the *Rhadinorhynchus* sp., noting that this was the first record of the genus in North Dakota. This primarily-marine genus attracted further attention in this study because North Dakota is out of its typical range, and it was recorded as infecting three species of game fish, implying the risk of economic damage caused by introduction of a new parasite into the Red River system and Lake Winnipeg.

Further analysis aroused suspicion about the reliability of the original identification of the specimen as being from this genus for the following reasons. First, the only two *Rhadinorhynchus* species listed by Hoffman (1999) as occurring in freshwater are parasites of salmonid fishes. One of the species was known from anadromous salmonids, identifying its distribution as coastal. Further, the original specimen identification was made by a student earning a master's degree and did not appear to have been confirmed by a taxonomic expert.

Further investigation revealed that several other species of Acanthocephalan worms are widespread in the Hudson's Bay drainage, including *Leptorhynchoides* spp. which are in the same family as *Rhadinorhynchus* sp. (T. Dick, pers. comm.). The specimens reported by Reinisch (1981) were very likely misidentified *Leptorhynchoides thecatus*. This species was reported from the lower Sheyenne River by Forstie and Holloway (1984), and infests a broad array of host species, including the genera of the host fishes reported by Reinisch (1981): *Morone* sp., *Perca* sp., and *Stizostedion* sp. (Hoffman 1999).

Based on the above-described investigation, the 1981 report of *Rhadinorhynchus* sp. was classified as a probable misidentification of another widespread species. Accordingly, *Rhadinorhynchus sp.* was classified as a non-BRA species for the purposes of this study and no further analyses were performed.

3.6.4 Nuisance Algae

The foregoing analyses brought attention to a few nuisance algae species, mostly reputed toxin producers, that appeared to have the potential to create negative effects downstream from the proposed outlet. These were analyzed more thoroughly through targeted literature and internet searches, and through consultation with experts. In each case, this further work uncovered information that removed some earlier concerns, but did not eliminate all concerns for all species. While none of the nuisance algae species were ultimately retained as BRA species for the reasons described below, the issue of toxic algal blooms appeared to be the most credible biota-transfer-related concern we encountered. This realization prompted the inclusion of the following discussion of the problem of nuisance algae, particularly species that occur in Devils Lake.

3.6.4.1 Algae of Devils Lake

Devils Lake is a large, shallow, warm and eutrophic body of water which ranges in salinity from fresh to brackish to saline, and which has a convoluted shoreline creating many protected bays and sub-basins that vary in wind exposure, water and chemical inputs, and degree of mixing with waters of other parts of the lake. Most researchers have studied environmental and biological characteristics of each distinct portion of the lake because many connections among sub-basins consist of narrow bay mouths or artificially constricted straits. The lake also exhibits a west-to-east chemical trend, as well as the usual horizontal and vertical zonation found in most lakes. The lake does howeever, appear to be polymictic and too shallow to develop a true hypolimnion. Due to the broad diversity of habitats, a large variety of algae with different life history traits have been recorded from the Devils Lake complex. With the exception of a few generalists, algal species tend to occupy particular niches in the landscape based on water flows, salinity, nutrients and other habitat characteristics.

3.6.4.2 Factors Controlling Algal Community Composition

Algal species, due to size, adaptability, rapid reproduction and ability to cling to other species for landscape movement are widespread and dispersed throughout the landscape. Limiting factors include such local determinants as physical and chemical attributes of habitats and microhabitats (e.g. temperature, silica, salinity, calcium, nitrogen, phosphorous, light availability, and the presence of other organic and non-organic factors in waters) and biotic interactions (competition, predation, etc.), but recent work has suggested that regional processes, primarily dispersal, can be equally important in many aquatic systems (Bohonak 1999, Boileau and Taylor 1994, Lukaszewski et al. 1999, Palmer et al. 1996, Shurin 2000).

3.6.4.3 Problems Associated with Nuisance Algae

When environmental conditions combine to create very favorable growth conditions for a given species in a given location, the population rapidly increases its reproductive rate, resulting in a “bloom”. Algae blooms can pose a number of problems relating to the blooming species' anatomical, toxic-chemical, and biological properties. Some algae have anatomical characteristics can cause them to become lodged in tissues of other organisms' delicate organs, such as gills, causing irritation, secondary infection, and functional inhibition through mechanical obstruction. Algal toxicity is generally related to the Cyanobacteria, whose toxins can be very potent. These toxins may kill or drive away many animals or make the algae unpalatable as food to many grazers. Essentially blooms of these species can replace "good" food with "bad". Algae also affect ecosystems when blooming species outcompete other organisms for nutrients, light, and oxygen. Accumulations of organic matter associated with blooms create a situation in which decomposition uses large amounts of available oxygen, leading to hypoxia (low dissolved oxygen) or anoxia (no dissolved oxygen). This situation deprives other species of needed oxygen, often causing mortality and a shift in ecosystem structure and function.

Sometimes cyanobacteria are not obvious components of algal communities, but may suddenly appear in greater numbers. This phenomenon is usually a result of the formation of algae “seed banks”, or caches of resistant, dormant propagules ("akinetes") in the sediments. These seed sources may be more widely distributed in waters than is often recognized. As described below, *Nodularia spumigena* blooms of great extent do not occur on a yearly basis in the water bodies where the species is common. During the years when there is no bloom, the chemical, climatic, salinity, temperature and other factors limiting the species do not converge to create the conditions necessary for a bloom. The full set of factors for a *N. spumigena* bloom are not fully understood, even though there are clear sets of parameters under which blooms occur (see description below). Generally, the toxic species of concern are widely distributed, suggesting that the above scenario of alternating dormancy and bloom is likely. It appears as though many cyanobacteria species fill ecological niches when they become available due to temporary changes in physical characteristics and the seasonal decline of other algal species.

3.6.4.4 Eutrophication and Cyanobacteria

Cyanobacteria often comprise a large and important group of primary producers in aquatic systems, but are usually viewed negatively because algae blooms are linked to the eutrophication of water bodies, and cyanobacteria account for more than 98% of algal blooms in some waters (Plinski and Jozwiak 1999). Eutrophication results from the enrichment of water bodies with limiting nutrients, usually nitrogen and/or phosphorus. Cyanobacteria blooms are often a response to nutrient loading, but some species are especially responsive to excess phosphorus. This is because, unlike the vast majority of organisms, many cyanobacteria species can exploit ("fix") atmospheric gaseous nitrogen as a nutrient. When phosphorus becomes over-abundant, most species increase growth and reproduction until the next most-limiting nutrient, usually nitrogen, becomes scarce. In such an environment, nitrogen-fixers have an advantage so they soon outcompete other species and dominate the community. Human activity tends to increase the availability of nitrogen and phosphorus in ecosystems, thus increasing the frequency of cyanobacteria blooms.

3.6.4.5 Cyanobacterial Toxicity

Cyanobacteria blooms worldwide present a variety of problems, particularly toxicity to animal species. These algae can produce toxins at any time, but when their populations bloom, the toxins become so abundant in the water that they reach levels that are dangerous to many types of organisms. Unfortunately, while a great deal of literature is available on the subject, it is not always clear when a bloom of cyanobacterial species will occur and when such a bloom will become dangerous. Bloom initiation seems to require the convergence of several environmental parameters to levels that are optimal for the blooming species, because these levels directly facilitate the species' growth and reproduction and/or because they hinder the growth and reproduction of competitors. The difficulty in understanding bloom initiation is complicated by the fact that the required conditions vary by species.

Several toxins have been isolated from individual algae species, and collectively they can affect organisms in many ways (Table 13). Cyanobacteria species produce one of two types of exotoxins (toxins secreted to environment): hepatotoxins or neurotoxins. Hepatotoxins attack the liver and have been linked to the deaths of humans and animals. Neurotoxins attack the nervous system and have been linked to the poisoning of livestock and shellfish poisoning (Falconer 1999). Some species also produce endotoxins (toxins held within individual cells), which are generally less toxic than the other types, and are only released upon death of each algal cell. Currently, the World Health Organization (WHO), and the US Environmental Protection Agency are devising health guidelines and standards for the measurement of toxicity for these species. Fitzgerald et al. (1999) proposed health alerts for each algal toxin be set at specific concentrations, suggesting that these levels were designed to be “protective of human health for lifetime use of the drinking water”.

Devils Lake Cyanobacteria genera that have been associated with toxic blooms are *Anabaena*, *Aphanizomenon*, *Microcystis*, *Nodularia*, *Oscillatoria*, and *Phormidium.* Past research has often failed to specify toxicity for individual species. Recent work has improved the situation, but many questions remain. For example, Sivonen et al. (1990) found that while a strong relationship existed between toxic blooms and *Anabaena spiroides*, toxicity tests on the organism were negative and the species has largely been removed from lists of toxic cyanobacteria (Steffensen et al. 1999).

3.6.4.6 Algal Toxins and Human Health

The EPA continues to develop guidelines for the monitoring and control of cyanobacteria related toxins in the environment. In 1998, the EPA suggested that problem algal species are best handled through good watershed management practices because they are not necessarily associated with fecal contamination. On the “Drinking Water Containment Candidate List”, the agency listed the broadly defined “Cyanobacteria (blue-green algae), other freshwater algae and their toxins” as a target for drinking water regulation. The agency has clearly had some difficulty with creating standards for such a widely defined group of toxins. USEPA (1999) stated:

> Algae are not typically a threat to public health in a drinking water supply. Concerns in potable water treatment arising from the presence of algae include: the ability to create large quantities of organic matter; the production of turbidity, tastes and odors in source water, and; the physical impact on the water treatment plant processes. Some species of blue-green algae are known to produce endotoxins which may affect human health. Algae can clog filters, resulting in reduced run times and an increase in backwash water needed for cleaning.

This language appears to understate the health hazards of algal toxins because there are many reports of poisonings from a variety of species. The National Institute of Health (NIH 1999) reported that the deaths of 75 dialysis patients at a clinic in Brazil have been attributed to microcystin in blood serum. Others in the same infestation suffered from blindness, nausea, vomiting, headache and visual disruption. There is ample evidence that cyanobactia have caused problems of toxicity in animals for more than a century. Increasingly, declining water quality due to expanded human land uses throughout the world is leading to larger blooms of greater duration and frequency.

Results of numerous literature searches indicated that most species present in Devils Lake appear to pose minimal threat to RRB waters affected by the proposed outlet. There are a few, however, whose presence in Devils Lake should be noted and treated with care. The species described below surfaced numerous times during literature searches as organisms that may require further research, and whose presence in Devils Lake, but not downstream, requires ongoing monitoring. Of the toxin-forming Cyanobacteria, most are not sufficiently dangerous to warrant concern, but three species requre some attention: *Anabaena spiroides*, *Anacystis nidulans,* and *Nodularia spumigena*.

3.6.4.7 Potential Nuisance Algal Species

Anacystis nidulans:

Anacystis nidulans, now generally referred to as Synechococcus leopoliensis, was analyzed further not because of a proclivity to dominate aquatic ecosystems, but only because the chemical and physical composition of the waters of Devils Lake, and potentially the Sheyenne River present ideal growing conditions for this species. Beyond this, it is a widespread species that may flourish with changes created by the outlet. In two hypereutrophic Uruguayan lakes, Aubriot et al. (2000) found that A. nidulans was quite adaptive to changing chemical conditions given high levels of phosphorus, suggesting that the eutrophic waters of Devils Lake may have an effect on the composition of algal communities and by extension, larger ecosystems.

Chaetoceros muelleri:

The diatom genus Chaetoceros consists of small planktonic colonies generally found floating near the surface of lakes. All the species in this genus have barbed setae, which become problematic when the species blooms and the setae cause colonies to become lodged in the gills of fish. Negative effects to the fish include inflammation and excessive mucus secretion, and infection often leading to death (Hatfield Marine Science Center, 2001). Rijstenbil (1988) found that C. muelleri became a dominant species in waters with fluctuating levels of salinity as the waters became less saline, but literature searches did not reveal any mention of C. muelleri as one of the problematic members of this genus. Also, the congeneric C. elmorei is already established in the Red River (Goldstein, unpubl. data) and has not been reported as a problem. Thus, even if outlet-induced salinity fluctuations in the Sheyenne River favor this species, there would not likely be an adverse effect on fish.

Further supporting a conclusion that *C. muelleri* does not harm fish, recent internet information indicates that the species is a common source of food for aquaculture**.** Huerta-Aldaz, et al. (1999) noted that rapid reproduction in this species facilitates its use as a food for other aquatic organisms. The species is sold as Instant Algae® by Reed Mariculture of San Jose, California as a shellfish food for aquaculture production, and it is a common mollusc food used by commercial producers. Molluscs and crustaceans produced via aquaculture have delicate gill structures like fish, so it is reasonable to conclude that this species is unlikely to pose a threat to fish, and the species was not investigated further.

Anabaena spiroides:

This species of Cyanobacteria was investigated because some studies described it as a toxin-producing species, and because it can be a bloom-forming species in eutrophic conditions. Recent surveys have found *A. spiroides* in the western portions of Devils Lake, including in Peterson Coulee, and on the Minnewaukan flats (K. Phillips, unpubl. data). This raised concern that transport of this species into Lake Ashtabula and even Lake Winnipeg, which already tend toward eutrophic conditions, could lead to blooms that could produce high toxin concentrations. Further analysis, however, revealed that this species' toxicity is very low, and that other species already present in Lake Ashtabula and the Red River (e.g. *Microcystis aeruginosa*) produce much more potent toxins.

A. spiroides is a widespread and common member of a genus known to produce toxins. Its success can probably be attributable to its nitrogen-fixing ability, its prolific population growth potential, and its tolerance of a wide variety of habitat conditions. The species can be an indicator of eutrophic conditions (Wu and Yang 1999) that responds positively to phosphorus loading (Cukor 1987). It can be very prolific; Keller and Pearl (1980) found that it maintainsed intense and prolonged biomass production in the epilimnion of a eutrophic Canadian lake, and Viner (1989) noted that sometimes it is found in monodominant masses.

A. spiroides is aggressive under certain water chemistry regimes, but it is sensitive to changes in water chemistry. It tolerates a range of salinity, but may become sub-dominant to more halophilic species at high salinity levels (Walker 1973). Webber (1963) found that *A. spiroides* was only present in large numbers in standing hard, alkaline water. Cukor (1987) found that phosphorus addition allowed it to dramatically usurp *Spirulina major* as the dominant alga in a North Carolina lake, but that experimental turbidity caused it to decline with most other species.

This species was selected for further analysis because of its apparent aggressiveness and toxicity, but neither of these reputed characteristics have been clearly established. Several authors have listed the genus *Anabaena* as toxic to cattle, but the role of *A. spiroides* in these incidents has been difficult to establish. Sivonen et al.(1990) found that *A. spiroides* was present in large numbers in toxic blooms, but many species occurred in the blooms, and the authors did not attempt to experimentally distinguish between toxic effects of individual species.

Several other authors considered *A. spiroides*' supposed toxicity to be too minor to cause concern. Steffensen et al.(1999) listed toxic cyanobacteria species, indicating that *A. spiroides* contains levels of toxins far below that of the problematic and widely recognized species *A. circinalis*. Baker and Humpage (1994) performed mouse bioassay tests on several of *Anabaena* species and found no significant levels of toxicity associated with any varieties of *A. spiroides*, but confirmed the high toxicity of *A. circinalis*. Review of these studies suggested the possibility that previous reports of *A. spiroides*' toxicity may have been flawed, based on incorrect identifications of *A. circinalis*, although there may be other explanations of the discrepancies in the literature. Whatever the cause, *A. spiroides* does not appear to be a significant threat to waters outside of Devils Lake. However, other than *Nodularia spumigena* (discussed below), no other species raised as much concern as *A. spiroides*, so further work may be warranted.

Nodularia spumigena:

<u>A. Distribution within Devils Lake and RRB</u>.

Nodularia spumigena is a toxic, primarily marine Cyanobacteria species that has been recorded from Devils Lake, but not from other waters of the RRB. However, other distribution information, combined with the data gaps described above, suggested that this species may already occur in Red River and Lake Winnipeg basin waters. A. Salki (pers. comm.) reported that *Nodularia* species have been reported in waters within the Lake Winnipeg drainage. He may have been referring to Bajkov's (1934) report of algae of the genus *Nodularia* occurring throughout the basin. Likewise, LaBaugh and Swanson (1988) reported an unidentified species of *Nodularia* in the Cottonwood Lakes Area (CLA), which is south of Devils Lake and the

Sheyenne River, just over the divide of the Missouri River drainage. As described above, the proximity of this area to the waters of the RRB suggests that the unidentified *Nodularia* probably has access to the Sheyenne River. These specimens could have been *Nodularia harveyana*, which Goldstein (unpublished data) identified from the Red River. However, the reliability of the identification may be in question (Goldstein, pers. comm.), and because *N. spumigena* is the most common and widespread species of the genus, all the above-noted specimens may well have been *N. spumigena*. This species has a global distribution, having been studied in such distant regions as the Baltic Sea and Australia, and it commonly occurs both in coastal waters and in saline lakes far inland, so overland dispersal must not be an important limitation on the species' distribution. Further, Round (1981) included *Nodularia* among the algal genera that occupy moist soil habitats, so terrestrial habitats may provide little resistance to the dispersal of these algae in low, frequently wet areas such as those surrounding Devils Lake and the surface waters of the RRB.

N. spumigena may also be less of a potential threat than in the past. As Devils Lake has become more diluted, this halophilic species appears to have declined. Even before the recent rapid rise in water level, the species was confined to the more saline East Bay and East Devils Lake portions of the lake (Sando and Sether 1993), far from the proposed West Bay intakes for the outlet project. Several years and a large quantity of diluting inflows later, Leland and Berkas (1998) also did not find the species in the western portions of the lake (e.g. West Bay, Six-mile Bay, Main Lake). Relatively low densities occurred in a minority of Creel Bay samples, and it was more dense in the eastern portions of the lake. Because Devils Lake water slowly flows from west to east, and prevailing winds are westerly, it is unlikely that the eastern accumulations of *N. spumigena* would ever be transported to West Bay and enter the outlet's pump intakes. The most recent surveys in the lake have not detected the species in any location, including Creel Bay, East Bay, Black Tiger Bay, and East Devils Lake (M. Fawley, K. Phillips, unpubl. data), so it is not clear that the species has survived the freshening of Devils Lake, although it almost certainly remains as a low-density population that could increase again with future salinity increases. If the species persists in the eastern part of Devils Lake, the No Action (natural spill) alternative (if it occurred), would be more likely to transfer it than either constructed outle alternative.

Based on the above information, this species was considered very likely to already be present in areas downstream of the proposed outlet. The outlet is unlikely to transport this alga because of its present distribution in the eastern parts of the lake. However, the potency of nodularin, the toxin produced by the species, suggested that periodic algae monitoring should be considered if the outlet is built.

B. Habitat factors and bloom formation.

Despite the open question of whether *N. spumigena* is present in the RRB and the low probability of significant numbers of algal cells being transported by the outlet, limitations in knowledge about the species' bloom-triggering conditions suggest caution and further study. As described below, the chemical determinants of *N. spumigena*'s success are not fully known, and the cause of blooms appears to be a haphazard congruence of independent physical and chemical habitat factors. Salinity may be especially important in inland waters because *N. spumigena* is primarily a marine species that has secondarily adapted to brackish and even fresh waters (Codd et al. 1994).

N. spumigena can form dense late-summer blooms in the oligotrophic, saline Pyramid Lake, Nevada. Unlike many other species of Cyanobacteria, *N. spumigena* forms floating mats, and is tolerant of ultraviolet solar radiation a few centimeters below the water surface. This appears to allow the species access to freshly dissolved atmospheric CO_2 (Horne and Galat 1985). The concentration of the species at the water surface during blooms undoubtedly increases toxicity dangers because it concentrates the algal toxin in water that is most likely to be ingested by animals, including humans.

A great deal of research into this species has been performed in the Baltic Sea as a result of periodic summer blooms that cover much of the surface of this low sub-saline sea. Kononen et al. (1996) describe the Baltic Sea as a nontidal brackish sea with large freshwater river inflow and occasional inflowing salt water from the North Sea. Over the past two decades, significant blooms of *N. spumigena* have occurred during July and August, the warmest season of the year for the sea. Various researchers (Kahru et al. 2000, Kononen et al.1996, Plinski and Jozwiak 1999) have found that a combination of relatively low salinity, seasonal calm waters, a low nitrogen-to-phosphorus (N:P) ratio, and warm temperatures (20-25°C) all contributed to the dominance of *N. spumigena* algal blooms in the Baltic Sea. *N. spumigena* seems to thrive on this combination of factors, but also is quite competitive when pulsating levels of nutrients and temperature occur. Blooms can develop rapidly, apparently in response to short-term changes in chemical and atmospheric conditions. Over a two-day period in July, 1993, Baltic Sea *N. spumigena* blooms tripled in size (Kononen et al. 1996). Like many algae, this species can use "luxury uptake" to collect and store phosphorus when it is abundant, giving it a store of the frequently limiting nutrient for leaner times. This ready supply of phosphorus must help fuel the sudden blooms that occur when other conditions converge to create ideal conditions for growth.

Determining the role of salinity in the individual and population biology of this species has difficult. The 1993 bloom described above occurred when a mass of dense, saline water at the surface was replaced by a flush of inflowing fresher, less dense water, suggesting that stratification, salinity fluctuations, and/or lowered salinity may contribute to bloom formation (Kononen et al. 1996). Jones et. al.(1994) determined that a four-month bloom of *N. spumigena* in Oriental Lagoon, Tasmania may have been stimulated by temporarily lowered salinity in the lagoon. Wasmund (1997) found that *N. spumigena* blooms only occurred within a specific salinity range, but temperature and N:P ratio appeared to play roles as well. Galat (1990) found that *N. spumigena* blooms broke down as fall temperature changes eroded Pyramid Lake's thermal stratification, and Wasmund (1997) noted that a bloom seemed to decline after wind speeds increased, suggesting that when wind-induced mixing broke down the established stratification, the bloom lost one of its key conditions for continuation.

The above examples and other literature allow the proposal of a set of conditions necessary for *N. spumigena* blooms. Salinity seems to be the limiting factor: when it is high, bloom initiation is suppressed, but when it is very low, the species becomes competetively inferior and is suppressed. Moderate salinity seems to fvor this species. Previous luxury uptake of phosphorus by "seed" populations prepares the population for rapid growth, and the onset of stratification during still periods can initiate the bloom.

C. Toxicity Hazard.

N. spumigena can represent a significant component of hepatotoxic algal blooms, frequently exceeding standard human and animal health limits (Baker and Humpage 1994). The blooms form a surface scum, and may be concentrated by currents or wind action. Steffensen et al. (1999) implicated the species in at least two major livestock poisonings in Australia and numerous poisonings in Southern Africa. In 1878, sheep, horses, dogs and pigs were poisoned and died at the margins of Lake Alexandria. In 1974 and 1975, a poisoning by this species caused the death of 34 sheep and 52 lambs in Southwestern and Western Australia. This species creates a foul odor and taste, so animals and humans tend to avoid intake of affected waters. However, in arid regions, where water is sometimes scarce, poisonings have occurred where the only available sources of water contained blooms of *N. spumigena*.

The same research suggests that while fish, crabs, and birds tend to detect and avoid the toxic blooms, recent declines in some of these populations may have some relationship to this species. Death in fish species due to this alga may be due to inability to avoid the toxins present or to oxygen depletion from decomposition of algae, clogging of the gills, or release of hydrogen sulfide during the decomposition process. Sheep who have ingested the alga “suffer difficult breathing, muscular weakness and may show paralysis or nervous twitching. They may lapse into a coma before dying quietly. Most commonly they are simply found dead near affected water. Sometimes the algal scum can be found of the forelimbs, lips and muzzle" (DAWA 1994).

A study by Edler et al. (1985) examined *N. spumigena* blooms dominating the Baltic Sea in 1983, and the bloom’s relationship to the death of domestic dogs. A 1983 bloom resulted in nine cases of illness in dogs either swimming in or drinking Baltic Sea Water. Poisoning occurred in all cases within one day of exposure. Symptoms included vomiting and apathy, resulting in death of all studied animals between 1-14 days from contamination. Tests of waters indicated that 90-95 % of blooms were composed of *N. spumigena*. In most cases, it appeared that the dogs ingested the toxin when licking their fur after exposure to the water. This suggested that only small quantities of toxin were ingested, but could easily have exceeded 1 g of nodularin, which would be 40 times the lethal dose, based on mouse assays. Despite this high toxicity, there were no reported bloom-related human deaths.

Toxins produced by *N. spumigena* are hepatotoxins. They are not destroyed by digestion; they inhibit digestive enzymes, and lead to dramatic cell deformation. This in turn causes structural changes in the architecture of tissues, and blood accumulation in the liver leading to blood loss and eventual death to animals. The pentapeptide nodularin has also been identified as a potent promoter of tumors (Falconer 1999). Currently, the World Health Organization is developing health guidelines for a number of species including *N. spumigena* (Fitzgerald et al. 1999).

D. Mitigation potential.

Steffensen et al. (1999) suggested that most toxic cyanobacteria tend to thrive in calm waters due to gas vacuoles that provide a certain degree of buoyancy control. This allows these species to maintain themselves in the water column while diatoms and other algal species are heavier and rely on turbulance to stay afloat. It has been surmised that the buoyancy of cyanobacteria allows access to atmospheric CO_2 and N_2. Thus mixing of waters and denying stratification may limit the growth of cyanobacterial blooms. Success using this technique has been variable, often it is assumed, due to incomplete mixing. This technique may also be difficult in much larger bodies of water where *N. spumigena* is often the dominant bloom species. Flowing rivers generally tend to limit the growth of cyanobacterial blooms, and the recommended technique for preventing such blooms if maintaining an adequate flow to prevent stratification. This again depends upon a combination of source waters and use.

If the Devils Lake outlet is constructed, and in the unlikely event of a subsequent *N. spumigena* transfer to the Sheyenne River, the species could be favored by salinity increases driven by the the discharge of Devils Lake water. The species tends to thrive in conditions where salinity is intermediate between fresh and saline. It also thrives where N:P ratios are relatively low. Flow would probably keep this alga in check in the Sheyenne and Red Rivers, but would also carry it into Lake Ashtabula and eventually to Lake Winnipeg. The species could possibly find favorable habitat in either of these lakes, but given the substantial dilution of salts by the Red river and its tributaties, Lake Winnipeg would probably remain too fresh to promote its growth. Lake Ashtabula would be more likely to be directly affected by more saline water introduced by the outlet. However, salinity alone should not induce blooms, and Lake Ashtabula is polymictic (Peterka and Reid 1968) so it would not provide the stratification that *N. spumigena* appears to require for bloom initiation and maintenance.

3.6.5 Other Salt-Adapted Species

The biota of Devils Lake have partly been determined by the brackish conditions of its waters. Young (1924) found the protozoa of the lake to be typical of those found in most any freshwater system, except for the notable absence of several types that apparently could not tolerate the high salt content of the lake in his time. On the other hand, he notes that the algae community was not very species rich, and nearly half the species were cyanobacteria, a likely result of salinity conditions. Vascular plants and aquatic animals can be seriously stressed by saline conditions, and during the lake's decline leading up to the 1940's, only one plant and one fish species remained in the various shallow ponds that remained of the lake (Young 1924).

More recently, as water has risen and become diluted, the Devils Lake community has become much more species rich and less characteristic of saline conditions. Nonetheless, several PBOC species are known to occur primarily in habitats with higher salinities than truly "fresh" waters (examples in Table 14; habitat preferences for all PBOC in Tables 9 and 10). These salt-tolerant species (halophiles) are assumed to have physiological adaptations to higher salt content, which allows them to survive habitat conditions that kill or stress true freshwater organisms. However, many PBOC species may not be known as halophiles, but may have adapted sufficient physiological plasticity to be considered habitat generalists with respect to chemistry. Such adaptation could be a species trait, or could be a local ecotype trait, so the lack of solid information (described above) on species' salinity tolerances may be further complicated by genetic variation within, as well as among, species. Given these limitations, the number of PBOC species that could benefit from salinity increases in the Sheyenne River is unknown.

The salt-tolerant biota that may take advantage of conditions created by the outlet may include species that could cause specific problems, but the more general problem is that high salinity could drive resident salt-sensitive (halophobic) species out, vacating their habitat and niche space which could then be exploited by the salt-tolerant species. These invading and/or usurping species need not outcompete the residents if physio-chemical conditions effect the same result for them.

Not only is total salinity important, but biota also appear to respond to differences in the chemical constituents that contribute to salinity. Devils Lake is a $NaSO_4$ (sodium sulfate) dominated lake, with approximately 50 % of total dissolved solids (TDS) occurring as sulfate. By contrast, Sheyenne River water is $MgHCO_3$ and $CaHCO_3$ dominated, with much less sulfate (approximately 25 % of TDS) and sodium than is found in Devils Lake. Obviously, the proposed outlet would raise sulfate and sodium levels in the Sheyenne River, and this change could create more favorable habitat conditions for sulfate-adapted species.

To determine how some species respond to water chemistry, LaBaugh and Swanson's (1988) algae-chemistry associations from the Cottonwood Lakes Area (CLA), North Dakota, were examined. Several algae species that occur in Devils Lake were also found in the CLA, which is roughly 60 miles south of Devils Lake, in the James-Missouri River drainage very near the divide between the Missouri River basin and the RRB. The study focused on algae communities associated with five characteristic water-chemistry environments found in wetlands of the region, including a $NaSO_4$ type, like Devils Lake, and a $MgHCO_4$ type, similar to the Sheyenne River. Table 15 lists genera and species included in the study that have also been recorded from Devils Lake. The comparison between each alga's density in each of the two types of systems may suggest how each would respond to water chemistry changes in the Sheyenne River resulting from a Devils Lake outlet. Some algae were found in much higher densities in $NaSO_4$ systems (e.g. *Lyngbya* sp., *Synechochoccus* sp.), suggesting that they would be favored by increases in sodium and sulfate in the Sheyenne River. A smaller number of taxa were less dense in $NaSO_4$ systems (e.g. *Aphanothece* sp., *Cryptomonas erosa*, *Rhodomonas* sp.), or showed little appreciable difference between system types (e.g. *Scenedesmus* sp., *Navicula* sp.).

Some taxa were PBOC and were found in much higher numbers in $NaSO_4$ waters (e.g. *Dactylococcopsis fascicularis*, *Gloeocapsa* sp., *Oscillatoria chlorina*, *Rhabdoderma* sp., *Synechochoccus* sp.), suggesting the possibility that they could become invasive downstream from the outlet, at least as far as sodium and sulfate levels remain high enough to favor them. These PBOC species could represent true new introductions to the Sheyenne River, but it seems more likely that they can already disperse to the river through existing routes but may not have found favorable habitat conditions in the past. It is likely that these species already occur in the RRB, and perhaps in the rivers themselves, if only as dormant propagules. Non-PBOC species are known to already exist in the Sheyenne and Red Rivers, but their numbers may be increased by inflowing conspecifics and by the chemical changes associated with the outlet.

Most of the species that could be favored by increased salinity or shifts in the chemical constituents of Sheyenne River water have not been found to be harmful. However, this group includes several cyanobacteria that can produce toxins (e.g. *Anabaena* sp., *Oscillatoria* sp.) and cause dangerous conditions when they bloom, as discussed above. The more subtle and intractable, but no less important, concern about salt- and sulfate-tolerant species is the indirect harm that could result from their outcompeting others and changing the algal community composition of portions of the Sheyenne River, Lake Ashtabula, and the Red River. Such changes could have effects on non-algae species as well, including disruption of food webs if unpalatable or undigestible species of Cyanobacteria become dominant.

3.6.6 Eutrophication Indicator Species

Several PBOC algae species are common indicators of eutrophic, or nutrient-enriched, waters. However, the species which are favored depends on which nutrients are enhanced. Presuming that Devils Lake water has higher total nitrogen concentrations that in the Sheyenne River, the outlet could raise nitrogen levels and N:P in the upper Sheyenne River, enhancing the invasibility of species that respond well to nitrogen addition.

Because Lake Ashtabula is already highly eutrophic, the outlet is unlikely to significantly alter algal communities of the lake, unless inflowing water carries higher nitrogen loads than in the past. Data reported by Peterka and Reid (1968) suggested that N:P is low in Lake Ashtabula (well below the Redfield ratio of 15:1), so nitrogen may be the limiting nutrient and the outlet could induce further eutrophication of the lake. Eutrophication usually causes series of cascading effects, ultimately leading to much altered communities based on algae that are especially adept at competing in high-nutrient conditions. Unlike salinity, high nutrient concentrations do not generally kill or stress non-indicator species, but they provide an environment in which indicator species can usurp niches, driving the former occupants to very low numbers or even local extirpation. Therefore, the indicator species are not the ultimate causes of community change, but they are the proximate causes. Nonetheless, when the Devils Lake outlet ceases to operate, the changes should be reversible as nutrient levels fall to original levels.

Nutrient loading affects saprobes, organisms that absorb nutrients from their environment, most directly. Saprobes include bacteria and Cyanobacteria, fungi, many protozoa, and algae, so the eutrophication indicators found among the PBOC species include Cyanobacteria in general, which are especially diverse and abundant in Devils Lake. Taylor et al. (1979a) listed the common U.S. algae genera according to their association with certain water chemistry parameters. It is difficult to interpret the meaning of these genus-level lists in the context of the proposed outlet, but those PBOC genera associated with low N:P ratios included *Chroococcus*, *Lyngbya*, *Merismopedia*, *Dactylococcopsis*, *Anabaena*, *Aphanizomenon*, *Scenedesmus*, and *Oscillatoria*, among others. If more accurate chemical and species data were available, the information provided by Taylor et al. (1979a) may be useful in predicting community changes in Lake Ashtabula under an outlet scenario.

3.6.7 Biota for Risk Assessmen (BRA)

The only two species classified as BRA were striped bass and Eurasian watermilfoil. Striped bass were selected because they are an exotic species that have been known to occur in Devils Lake in the recent past, and may still occur there. This possibility presents a risk of potential transfer to the Sheyenne River. Eurasian watermilfoil is not known to occur in Devils Lake, but a small population has been identified in the Sheyenne River below Baldhill Dam. Because the river would be affected by high streamflows from a Devils Lake outlet, a risk of this species being transferred downstream was noted.

The assessment of risk related to exotic species invasions is particularly complex. Unlike chemical contaminants, which usually allow quantitative measures, living organisms react to their environment, reproduce, and adapt, in ways that cannot be quantified accurately (CENR 1999). Further complicating risk assessment in the context of this biota transfer analysis is the fact that the many data gaps encountered in this study precluded the proper problem formulation that should begin any risk assessment. Nonetheless, this report follows assessment procedures based on principles used in federal government ecological risk assessments (CENR 1999; USEPA 1998). According to these principles, risk assessments for the two BRA species begin with problem formulation and are followed by characterizations of "exposure" (of downstream communities to BRA species) and effects (ecological and economic). Assessments concluded with qualitative assessments of the likelihood of exposure risks and the magnitude of effects as negligible, low, moderate, or high. The degree of certainty regarding these assessments were also qualitatively determined.

3.7 RISK ASSESSMENT: STRIPED BASS (*Morone saxatilis*)

Basic life history and other biological/ecological information about striped bass are described in Section 3.6.1.4 above. Also as described above, concern about this species originated with knowledge of prior stocking in Devils Lake (in 1977). This stocking occurred during only one year, and it has been many years since any adult striped bass have been reported by anglers. No evidence of striped bass reproduction in Devils Lake has been found, and suitable spawning habitat is apparently absent from Devils Lake. However, large adults may still exist in the lake, and there remains a small possibility that they have found a way to reproduce. Adult fish would be precluded from entering the proposed outlet works by fish screens at the intakes, so only immature stages could be transferred directly to the Sheyenne River via an outlet project. The possibility that immature striped bass would occur in Devils Lake appears remote, at most, but the following assessment assumes that the possibility exists.

3.7.1 Characterization of Exposure

Under the scenario of striped bass transfer to downstream habitats, "exposure" refers to the introduction of sufficient number of striped bass individuals to establish a locally persistent population. This persistence could result from reproduction in the local habitat or from repeated introductions from an upstream source population. This characterization of exposure addresses the likelihood of introduction and establishment by considering such factors as the species' tendency toward invasiveness, pathways for transfer under an outlet scenario, and suitability of downstream habitats for striped bass survival and reproduction.

3.7.1.1 Striped bass habitats and invasiveness.

Striped bass are a North American marine species – there are no native freshwater populations. In marine environments, they are amphidromous, migrating repeatedly between marine and estuarine habitats for feeding and reproduction. The native range includes much of the east coast of North America as well as a disjunct population in the Gulf of Mexico. An introduced population expanded from a small number of fish stocked in the Sacramento River to include much of the west coast of North America. This demonstrates that striped bass have the *potential* to be invasive, at least in marine environments, since they have dramatically expanded their range to include west coast rivers from the Columbia River south to northern Mexico. Colonization of Pacific coast watersheds occurred as a result of the extensive migration of mature and immature striped bass in search of prey.

Invasion and colonization in *freshwater* habitats appears to be very rare, the Colorado River being the only example identified in this review. Striped bass were stocked in several reservoirs of the Colorado River beginning in 1959 and have become established in Lake Mead, Lake Powell, Mohave Lake, and Lake Havasu (Giusti and Milliron 1987). Eggs and larvae are seasonally entrained in the pumps of the California State Water Project and transferred to several downstream water bodies. These entrained life stages survive in the downstream reservoirs as far as the Imperial Valley Canal System, where they provide sport fisheries. However, they do not reproduce in these downstream waters and rely on recruitment via entrainment in pumped water (Chris Hayes, Cal. Dept. Fish and Game, personal communication). This example demonstrates that it would be possible for larval and perhaps juvenile striped bass to be entrained from Devils Lake via pumped water.

There is no evidence that the striped bass stocked in Devils Lake have ever reproduced. An estimated 30,000 hours of netting on Devils Lake since striped bass were introduced in 1977 has only produced a single adult fish. Striped bass have been widely introduced in North American freshwater habitats, particularly in two story (i.e., stratified) temperate lakes and reservoirs of the central and southern United states (Fuller et al. 1999). With a very few exceptions, these freshwater populations are maintained by annual stocking since it is relatively common for stratified lakes and reservoirs to have suitable lacustrine habitat for juveniles and adults, but very uncommon for them to have suitable reproductive habitat. Naturalized, self-sustaining populations have only become established in a few temperate freshwater systems, including the Kerr Reservoir in Virginia and North Carolina, the Santee-Cooper Reservoir in South Carolina, Keystone Reservoir in Oklahoma, the Colorado River, and Lake of the Ozarks in Missouri (Setzler et al. 1980, Crance 1984). Two of these populations, the Santee-Cooper and Kerr reservoirs, were unintentionally created by constructing dams and landlocking existing spawning stocks (Setzler et al. 1980, Rulifson and Laney 1999). Striped bass were introduced in the other three systems and then began reproducing successfully. These three freshwater systems are exceptions to the most common result of stocking striped bass in freshwater, that is, landlocked striped bass seldom reproduce successfully. Although the species has been stocked in hundreds of inland waters, self-sustaining populations have only become established in a few water bodies.

The characteristics of striped bass spawning habitats are well documented. Striped bass spawn in the spring at high discharge rates. Males typically reach the spawning grounds first with females entering later. There may be several spawning episodes in the spring. Fecundity varies with size, but large females weighing 10-15 kg may release up to several million eggs (Setzler et al. 1980). Water velocities must be high enough to keep developing eggs suspended, and higher flows are generally associated with better survival and greater recruitment (Setzler et al. 1980, Crance 1984). Minimum water velocity for spawning is about 30 cm/sec, with optimum velocities in the range of 100-200 cm/sec, and an upper limit reported to be 500 cm/sec or "unknown" (Setzler et al. 1980, Crance 1984, Hassler 1988). Striped bass spawn in depths up to 15 m with optimum spawning at 2-9 m (Crance 1984). They will not spawn in shallow water. Suitable spawning substrates range from coarse sand to boulders/rubble (Setzler et al. 1980, Crance 1984). Spawning occurs at water temperatures ranging from 14 to 23 °C, with peak spawning activity at temperatures from 16.7 to 19.4 °C (Setzler et al. 1980, Crance 1984). Spawning is initiated by rapidly increasing water temperature and any decrease will interrupt spawning and cause spawners to drop downstream. At the lower end of the thermal range, hatching occurs in 3-4 days, while hatching at the upper end of this range is completed in less than 30 hours (Setzler et al. 1980, Hassler 1988).

Eggs must remain suspended in the current during this period and the larvae must be transported to lacustrine habitat soon after hatching. Larvae inflate their swim bladder 5-10 days post-hatch, and at that time, they are no longer dependent on high flows to stay suspended in the water column. Thus, successful spawning and incubation requires that the water velocity is adequate to deliver the larvae to the lake or reservoir immediately after hatching. The eggs of fish that spawn too early, or at low flows, will hatch before they reach suitable lacustrine habitat. Late spawning, or excessive flow, will result in eggs reaching the lake or reservoir before they hatch and settling to the bottom where they will not survive. Thus, successful spawning requires a precise combination of temperature and flow, in order to deliver the developing larvae to the lake at the right time. As a result, losses through the larval stage are high, even in rivers with suitable spawning habitat. Egg mortality in the Santee River, a spawning tributary of the Santee-Cooper Reservoir, was reported to be 80% per day (Bulak et al. 1993). Setzler reported 94% total mortality from egg deposition through the larval stage (Setzler et al. 1980).

3.7.1.2 Potential for striped bass reproduction in Devils Lake and Red River basin waters.

Striped bass have a high potential reproductive rate. Females deposit up to several million eggs, as described above. However, reproductive success only occurs in a narrow range of environmental conditions, particularly among landlocked populations. Suitable spawning habitat is only found in large rivers in temperate climates. Spawning reaches must be deep and fast flowing with coarse substrates. Spring runoff must warm rapidly and be of a very high volume. In order to provide some perspective on the size of spawning reaches and the quantity of flow, the following table provides mean monthly discharges during spawning for the five freshwater populations noted above.

Mean monthly discharge during striped bass spawning in five freshwater systems. Mean monthly discharge data from USGS.

Population – Spawning River	Peak Month of Spawning	Mean Monthly Discharge (cfs)
Kerr Reservoir, Virginia – Roanoke River	April	11,720
Santee-Cooper Reservoir, South Carolina		
Congaree River	April	11,500
Wateree River	April	8,240
Lake of the Ozarks, Missouri – Osage River	May	9,240
Lake Havasu, California – Colorado River	May	11,220
Keystone Reservoir, Oklahoma – Arkansas R.	May	8,960

In comparison, mean inflows to Devils Lake in the spring are as follows:

Spring mean monthly discharge for major inflow sources to Devils Lake, North Dakota. Mean monthly discharge data from USGS.

Inflow Source	April	May	June
Channel A	311	260	68
Mauvais Coulee	192	59	12

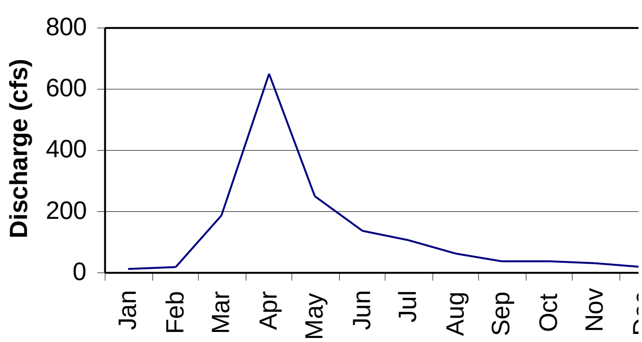
Wetter conditions in the last decade have produced higher runoff to Devils Lake in some months, particularly in Channel A where the mean monthly discharge exceeded 1,000 cfs in April 1995 and again in May 1997. However, it is very unlikely that even higher than normal spring runoff in wet years has produced conditions that would support striped bass reproduction. Devils Lake is also at the extreme northern limit of the distribution of striped bass and spring runoff may be too cool for striped bass reproduction. Although spring spawning conditions in Devils Lake tributaries bear no resemblance to the rivers described above, this risk assessment takes a conservative approach and assumes that striped bass still remain in Devils Lake, that they reproduce in the inlet channels and coulees, and that eggs, larvae, or juvenile striped bass may be entrained in the outlet works and reach the Sheyenne River.

Striped bass require lacustrine habitat as juveniles and adults. Striped bass have been stocked in many large lakes and reservoirs. The first lake or reservoir they would encounter moving downstream in the Sheyenne River is Lake Ashtabula, created in 1950 by the construction of Baldhill Dam. Lake Ashtabula is relatively large, being approximately 5,200 acres in size, 27 miles long, with about 78 miles of shoreline. There are two bridges/causeways that divide the lake into three sections. The average depth is about 13 feet, with a maximum depth of about 45 feet near Baldhill Dam. Lake Ashtabula water levels are managed for flood control benefits by drawing the lake down 5-10 feet in late winter and refilling it during spring runoff. Mean monthly inflows to the lake are shown in the figure below. Spring runoff in the Sheyenne River is very turbid and the river carries large volumes of sediment during high flows. As a result, sedimentation is rapidly filling in the reservoir from upstream to downstream. The upper basin has filled significantly since the reservoir was formed. Spring turbidity and sedimentation may inhibit aquatic plant development by smothering emerging shoots.

The few freshwater systems that support striped bass reproduction have much larger inlet rivers and much different hydrology. Lake Ashtabula, like Devils Lake, does not appear to have suitable spawning habitat to support striped bass. Although both of these water bodies could support juveniles and adults, it is extremely unlikely that striped bass could reproduce in either.

3.7.1.3 Downstream habitats potentially affected.

Only a few large lakes and reservoirs support reproducing striped bass populations. Striped bass would not establish populations in riverine habitats of the Red River, therefore, much of the Red River basin would not be affected by striped bass. Lake Ashtabula would be suitable habitat for striped bass, but it is not likely that they would reproduce there. However, if striped bass have been able to reproduce in Devils Lake (a necessary condition for a transfer to Lake Ashtabula), then it would seem likely that they would reproduce in Lake Ashtabula because the Sheyenne River inflow would provide spawning habitat of equal or better quality to that provided in Devils Lake.



Mean monthly flow in the Sheyenne River near Cooperstown, upstream of Lake Ashtabula, North Dakota. Data from USGS.

Striped bass juveniles and adults tolerate a wide range of water quality conditions. Lake Ashtabula is eutrophic to hyper-eutrophic. It is on the EPA list of impaired waters and a high priority for TMDL development. Maximum summer water temperatures are generally 22-25°C, well below the upper limit tolerated by striped bass. The lake is generally well mixed in summer due to wind induced mixing and does not typically stratify during open water periods. As a result, dissolved oxygen in deep waters is not depleted during open water. Stratification during the growing season would likely lead to poor hypolimnetic water quality due to eutrophy. The lake may stratify during winter due to ice cover and very low inflow. Although water quality problems due to nutrient enrichment are typically less significant in winter, there may be some dissolved oxygen depletion during winter. There may have been some winter dissolved oxygen depletion and fish kills in the 1970's (Gene VanEeckhout, ND Dept. Fish and Game, personal communication). Low winter dissolved oxygen could make Lake Ashtabula unsuitable for striped bass.

Lake Winnipeg is the only freshwater body downstream of Devils Lake that has a large tributary with high flows and the potential to provide spawning habitat similar to known spawning rivers for striped bass. However, Lake Winnipeg is much further north than any other lake or reservoir that supports a striped bass population. Striped bass spawn in peak spring flows during periods of increasing temperature. The Kerr and Santee-Cooper Reservoir populations are located in the southeast Atlantic coast, draining portions of the southern Appalachians. Suitable flow and temerpature conditions occur in Arpil in these basins. Three Rocky Mountain drainages have suitable spawning habitat, with suitable temperature and flow conditions in mid to late May. Peak flows into Lake Winnipeg occur in April. Water temperatures may be too low at this time for striped bass spawning. Lake Winnipeg may be beyond the range of striped bass and it is uncertain whether Lake Winnipeg habitats could support striped bass.

<u>3.7.1.4 Potential mechanisms for transfer under outlet scenarios.</u>

There are two potential pathways that might allow striped bass from Devils Lake to invade downstream waters. First, eggs, larvae, or possibly small juveniles (depending on the intake screen mesh size) could survive entrainment in the outlet works, as evidenced by the transfer of eggs and larvae from the Colorado River to California waters. However, there is no evidence that striped bass have ever reproduced in Devils Lake, as described above. Further, it is extremely unlikely that eggs could occur near the pump intake, if at all, because the only areas that are even remotely suitable as spawning habitat are at the mouths of Channel A and Mauvais Coulee, which are not near the Peterson Coulee proposed outlet site.

It is possible that, if they occur in Devils Lake, juvenile striped bass could be taken by bait fish collectors and released into other waters. However, this seems unlikely because it is illegal to trap bait fish in Devils Lake (Randy Hiltner, ND Dept. of Fish and Game, personal communication) so only small-scale, clandestine collecting could occur, and juvenile striped bass are recognizable as something other than a bait fish species (e.g. cyprinids). It is unlikely that sufficient numbers to start a population would be taken and transferred in good condition to Lake Ashtabula or elsewhere. Also, this possibility exists at present, and it is unlikely that an outlet project would increase its likelihood.

Because juvenile striped bass do not appear to be present in Devils Lake, adults are the second pathway for invasion of downstream waters. Adult striped bass could be transferred illegally by anglers. This is also an existing possibility that would probably not be appreciably increased by an outlet project. Under any scenario, striped bass are extremely scarce in Devils Lake. Anglers have submitted three striped bass for "whopper club" status, the most recent being June 1993 (Steinwand et al. 1996). No striped bass have been reported from Devils Lake since 1993 (Randy Hiltner, ND Dept. Fish and Game). If any striped bass remain in Devils Lake, it is most likely that they are remnants of the original 1977 stocking. The remaining fish would be very large and difficult for anglers to capture and transport to other waterbodies. Their scarcity would make it very difficult to illegally transport and stock adequate numbers of both sexes to support a breeding population. Thus, illegal stocking appears to be a very unlikely means of invasion of downstream waters. The state of North Dakota has no plans for future striped bass stocking.

With regard to entrainment in the outlet works, screening at the outlet would ensure that adult striped bass are not passed downstream.

3.7.2 Characterization of Ecological Effects

The most important ecological effects of striped bass would likely result from biotic interactions between them and native species, thus affecting fish community dynamics and possibly having some trickle-down cascading effects through the food web. However, such cascading effects would likely be insignificant, because striped bass would, if anything, replace some top predators in the communities, taking over their ecosystem roles.

Existing game fish in Lake Ashtabula include walleye, northern pike, white bass, yellow perch and black bullhead. White bass are a non-indigenous species that has become established in the lake and is now very abundant (Petreka and Koel 1996). Walleye and northern pike are maintained by annual stocking – since 1995, annual stocking rates have been about 104,000 walleye fingerlings and 219,000 northern pike fingerlings with additional northern pike fry stocked in some years. Yellow perch fingerlings are also stocked in some years.

In general, striped bass would compete with other pelagic piscivores in large lakes and reservoirs. Specifically, striped bass could compete with lake trout, walleye, and brown trout. The former two species are important recreational species in Lake Winnipeg. Walleye are an important recreational species in Lake Ashtabula. Brown trout are not present in either Lake Winnipeg or Lake Ashtabula.

Striped bass are voracious opportunistic piscivores, so they can have the effect of reducing or even locally extirpating prey species. Previous freshwater introductions have been associated with reductions in clupeid populations, particularly gizzard shad and alewife (Fuller et al. 1999). Because clupeids are not present in Lake Ashtabula or Lake Winnipeg, striped bass would prey on other forage species. Potential prey in Lake Winnipeg could include goldeye, cisco, lake whitefish, other coregonids. Fry of the various salmonid species could be vulnerable to predation, as has occurred in other locations where striped bass have been stocked. Cyprinid species inhabiting open waters of either Lake Winnipeg or Lake Ashtabula would also be potential prey items.

Information is lacking in several areas that are crucial to assessing striped-bass-related ecological effects of a Devils Lake outlet. Most important, definitive assessment of the presence or absence of striped bass in Devils Lake would resolve issues related to their downstream dispersal. However, the difficulty of proving a negative outcome (absence of the species in this case) could make the cost of such a study prohibitive. Also, as is always the case when species are introduced into novel environments, the behavior (prey choice, spawning, etc.) and adaptability of striped bass in Lake Ashtabula and/or Lake Winnipeg cannot be predicted, especially because these habitats are so far beyond the northern limit of the range of successful introduced populations.

3.7.3 Characterization of Socioeconomic effects

3.7.3.1 Existing conditions on Lake Ashtabula.

Lake Ashtabula is a popular recreation resource in eastern North Dakota. The 5,234-acre lake is impounded by Baldhill Dam, which is approximately 12 miles upstream from Valley City. Upon completion in 1950, this Corps project was primarily intended to serve as a water supply facility to augment low flows on the Sheyenne River and on the Red River; however, it is currently operated for flood control and recreation purposes, as well. In 2000, the lake received 165,200 visitors who spent more than 2.6 million visitor hours at the lake. The lake has a popular sport fishery consisting of walleye, northern pike, white bass, yellow perch, and black bullheads. Its facilities include four campgrounds, three swim areas, seven boat ramps, and 250 acres of associated lands.

Recent user surveys conducted by the US Army Corps of Engineers indicate that recreationists on Lake Ashtabula pursue the following activities: fishing (55%), boating (36%), camping (25%), picnicking (23%), hunting (17%), swimming (15%), sightseeing (7%), and water skiing (4%). Approximately 98% of the lake recreation occurs during the open water season. A 1999 creel survey from May 1 through October 31 documented almost 106,000 angler hours, 27,000 days, and 12,000 trips. The ratio of boat angling hours to shore angling hours was 4.51 to 1.00.

3.7.3.2 Existing conditions on the Red River of the North.

Recreational fishing is a fundamental economic activity for the counties and towns that abut the Red River of the North (Red River) in North Dakota, Minnesota and north into Manitoba, Canada. Angler surveys for these states and the Province of Manitoba indicate a vibrant fishery with an abundance of fish species and angler opportunities.

A 1994 creel survey in Minnesota indicated that 90% of the respondents were fishing from shore, with the remainder fishing from boats (Topp, 1996). There were an estimated 159,723 angler hours of fishing during the 4-month survey (May to September, 1994), with the highest effort in May and least effort in July. The study area was divided into geographic zones, and estimated fishing pressure varied from 30 hours/km in Zone 3 north of Grand Forks to 5,668 hours/km in the Grand Forks area. More than 70 % of the total effort was from shore anglers.

Channel catfish were the most sought-after fish in the zones north of the confluence with the Sheyenne River. The overall catfish catch rate for all zones was 0.28 fish per angler hour for shore anglers and 0.14 fish per hour for boat anglers. Interviewed anglers reported 21 fish species or species groups (identifications not confirmed) in the Red River: chestnut lamprey, goldeye, mooneye, northern pike, common carp, shiner spp., quillback, sucker spp., bigmouth buffalo, redhorse spp., bullhead spp., channel catfish, stonecat, burbot, rock bass, sunfish spp., smallmouth bass, black crappie, yellow perch, sauger, walleye, and freshwater drum.

Of all anglers surveyed, 24% had fished the Red River for more than 25 years. Over 90% of the anglers had driven to their fishing spot. Only 31% of the anglers were from Minnesota, while 62% were from North Dakota. Most anglers that traveled from out of the area tend to fish in downstream reaches; however, much of the angling effort is concentrated in the upstream areas, where a typical angler is someone who lives in an urban area and heads to the river to fish for the day. The river represents a very important social and recreational resource for the urban areas along the river because the angling options for many residents are limited.

An economic survey of the anglers was also conducted in conjunction with the creel survey[1]. As shown in the table below, boat anglers, on average, spent more ($47.93) on operating expenses

[1] All costs in this report have been updated to 2001 dollars.

per angler day than shore anglers ($12.16). The operating expenses per day averaged $20.17. The biggest expense for shore anglers was bait at $3.45 per day, while the biggest expense for boat anglers was lodging at $15.58 per day. Other expenses for both groups included gas and food. Total fishing related expenses, including operating expenses, equipment costs, licenses, land ownership, etc., for the four-month survey period were estimated to be $2,047,931. Operating expenses are generally 44% of total angling expenses.

Angling Pressure Estimates and Expense Estimates
Red River, Minnesota, May 1 to September 5, 1994

	Angling Hours*	Angling Trips	Operating Expenses	Operating Expenses per Trip	Total Expenses
Shore Anglers	74,248	26,613	$323,570	$12.16	$735,386
Boat Anglers	41,144	7,677	$367,992	$47.93	$836,345
Total	115,392	34,290	$691,562	$20.17	$1,571,731

* Zones 1,2,3,4 and 6 from Topp (1996). These include all areas downstream of the Sheyenne/Red River confluence.

Minnesota's Red River winter fishery was not examined in detail in the 1994 survey; however, the report discussed a few notable facts regarding ice fishing. There were 35 fish houses counted during an aerial survey of the Red River on January 31, 1994. About 21% of the respondents to the 1994 economic survey said that they have fished on the Red River in the winter.

A random survey of angler use and sport fishing catch was conducted on the North Dakota side of the Red River during the open water fishing period of March 15 through October 31, 2000 (Brooks and Schlueter, DRAFT 2000). Anglers logged an estimated total of 194,981 hours, with 76,539 hours attributed to fishing from boats and 118,442 hours attributed to shore anglers during the 7½-month period. Fishing effort was lowest at the beginning and end of the study (March and October) and highest in May. Approximately 15% of Red River anglers fished from a boat and 85% fished from shore.

Channel catfish comprised the largest percentage of fish caught and harvested by anglers during the survey period. The overall catch rate was 0.26 fish per hour. Anglers interviewed also targeted walleye, sauger, northern pike, goldeye, freshwater drum, smallmouth bass, rock bass, bullhead, carp, redhorse, crappie, stonecat, yellow perch, sunfish, sturgeon and white sucker.

Five percent of the anglers interviewed were non-residents. The mean distance of one-way travel to the Red River was 34 miles, with boat anglers traveling approximately three times as far as shore anglers. Approximately 74% of the anglers were from North Dakota and 21% were from Minnesota.

Brooks and Schlueter (2000) used information from several sources to estimate the economic value of the Red River fishery. Based on an estimated value of a local fishing day of $41.67 (willingness-to-pay, updated to 2001 dollars) for residents and $623.48 for non-residents, the economic value of the fishery from March through October 2000 was approximately $4,590,941.

Although the winter fishery was not examined in detail in the study, 14% of the respondents stated that they do fish on the Red River during winter months. Lewis, *et al* (1998) present additional statewide data for North Dakota on ice fishing. This information does not pertain to the Red River alone; however, it is important for highlighting the economic impact of the sport on the Red River. The report estimates an average daily expenditure of $134.31 (2001 dollars) and an average of 10 days spent ice fishing for North Dakota resident ice anglers.

Lysack (1986) conducted a creel survey of Red River anglers in Manitoba from St. Andrews lock at Lockport to the mouth of Netley Creek in 1982. The creel survey design considered only fish that anglers harvested. Fish species harvested (identifications not confirmed) during the open water period of the survey were freshwater drum, sauger, walleye, channel catfish, goldeye, pike,, sucker, bullhead, burbot, rock bass, mooneye, white bass, perch, and carp. Lysack (1986) stated, "The Red River fishery receives the highest amount of angling effort in Manitoba and exploits the most diverse array of species." Estimated angling effort on the Red River in the study area was 285,933 angler hours from May 15 to October 30, 1982. This is a very intensively fished area with angler effort exceeding 10,000 angler hours per kilometer.

The study including daily roving surveys of the winter fishery conducted from December, 1982 to March 1983. During the winter, walleye, northern pike, sauger, and yellow perch were the major species harvested. Construction of ice fishing shelters began in late December. Angling effort steadily increased through January into late February (Lysack, 1986). Typically, anglers spent about three hours fishing per day throughout the winter.

Sport anglers spend $6 to $10 million (US) annually in Manitoba. The Red River is the most important sport fishing destination in Manitoba and accounts for nearly 20% of the total value of the $50 million (US) sport fishing industry in Manitoba. In addition, there is an important bait fish harvest in the Red River and the south basin of Lake Winnipeg that returns about $320,000 (US) annually to licensed dealers.

The main form of recreation on the Red River in Minnesota, North Dakota and Manitoba is fishing; however, other active recreation activities enjoyed in and near the rivers and lakes (including Lake Ashtabula and Lake Winnipeg) are boating, water skiing, canoeing and swimming. Passive recreation activities include: biking, camping, cross-country skiing, hiking, horseback riding, picnicking, pleasure driving, walking/jogging and hunting. Table 1 presents information from the *North Dakota State Comprehensive Outdoor Recreation Plan* (1996 – 2000) (SCORP) indicating that the average household in Planning Regions 4, 5 and 6 along the Sheyenne and Red Rivers enjoys about one week each year boating or water skiing, one day canoeing, and at least some time swimming. The study does not distinguish between swimming in pools and swimming in lakes and rivers, so the estimates provide little information regarding Red River recreational swimming.

Annual Household Participation in Active River Recreation
North Dakota Planning Regions 4 and 5

Activity	**Region 4**		**Region 5**		**Region 6**	
	Days	% of households that participate	Days	% of households that participate	Days	% of households that participate
Boating/Water Skiing	6	42	9	48	6	40
Canoeing	1	14	1	17	<1	9
Swimming	12	44	11	44	9	35
Total	*19*		*21*		*16*	

The Minnesota SCORP, dated 1995-1999, does not include information on boating, water skiing, canoeing or swimming along the Red River. Minnesotans are, therefore, assumed to participate in these activities at rates similar to that of North Dakotans.

Other recreation activities that often take place near lakes, rivers, and streams include: biking (paved and unpaved trails), camping, cross-country skiing, hiking, horseback riding, picnicking, pleasure driving, walking/jogging and hunting. The aesthetic appeal and associated flora and fauna from nearby waterways often enhance enjoyment of each of these activities. The North Dakota SCORP indicates that the most popular of these activities in Regions 4, 5, and 6 is walking/jogging, especially on paved trails. In those regions combined, household participation in walking/jogging is 90 days each year. Biking (49 days), pleasure driving (44 days) and picnicking (23 days) are also very popular activities in the regions bordering the Sheyenne and Red Rivers. Camping (12 days), hiking (9 days), horseback riding (8 days), and cross-country skiing (3 days) are other important recreation activities in the region.

Benefits from participation in all of the recreation activities discussed above (including fishing and boating) can be broken into four categories (Ohio SCORP, 1993): 1) personal benefits; 2) socio-cultural benefits; 3) environmental benefits; and 4) economic benefits. Personal benefits focus on better physical health and improved mental state through stress relief and improved quality of life and self-image. Socio-cultural benefits include factors such as family bonding and historical/cultural appreciation. Environmental benefits range from increased awareness of the environment to increased political involvement in political issues. Economic benefits associated with participation in outdoor recreation activities include: increased local and regional economic activity, contribution to net national economic development, increased tax revenues, less work absenteeism and job turn-over, increased productivity, increased employment opportunities, and reduced health costs.

3.7.3.3 Existing conditions on Lake Winnipeg.

Manitoba's 100,000 lakes cover approximately 17% or 39,000 square miles of its surface area. Fishing is an important economic activity in Manitoba, Canada. There are three statutory divisions of angling in Manitoba: domestic, commercial, and recreational. Much of the fisheries information provided below is province-wide and is not separated for individual lakes. Information specific to Lake Winnipeg has been provided whenever possible.

Manitoba's progressive fish management combined with strong conservation and selective harvest programs make it a world leader in sport fishing. Angling is a popular source of recreation for residents and visitors to Manitoba. The province’s abundant lakes and rivers are home to over 80 species of fish, with anglers likely to catch about 30 different species. The most sought-after species are walleye, northern pike, yellow perch, smallmouth bass and channel catfish. Walleye, northern pike and yellow perch account for 83% of all fish kept. Licenses, and corresponding limits, are also issued for many sportfish species in Manitoba, but the composition of the fish community in Lake Winnipeg is not fully known. Because Lake Winnipeg has interprovincial and international watersheds draining into it, the lake has been invaded by foreign species such as carp, smallmouth bass, black crappie, white bass and rainbow smelt. Some of these species, such as smallmouth bass, have been stocked in other lakes, but their spread has been uncontrollable. Other species have been introduced accidentally with the increased mobility of boats between water bodies. The lake's sport fishery is little studied because it is not particularly popular, and less important than the commercial gill fishery (W. Lysack, pers.

comm.). Therefore, most of the comments below pertain to the province as a whole. It is unknown how well they characterize Lake Winnipeg.

Overall success for sport fishermen in the province has improved according to five-year surveys on sport fishing done by Manitoba Natural Resources and the federal Department of Fisheries and Oceans. Preliminary results from the 2000 survey indicate that approximately 184,000 angling licenses are sold annually in Manitoba and about 190,000 Manitobans fish annually in the province (Wall, 2002). An unknown number of Canadians under 16 (estimated to be about 49,000) and Manitobans 65 and over also fish, but are not required by law to purchase licenses. Nonresident license sales were approximately 43,000 licenses. Table 2 provides a summary of harvest information for all recreational anglers in Manitoba from 1994. Only one-quarter of all fish caught are kept.

Summary of Fish Harvested by All Anglers in Manitoba

Fish Caught		Fish Kept		Weight of Fish Kept		Weight of Fish Eaten	
Total (in lbs.)	Avg. Per Angler	Total (in lbs.)	Avg. Per Angler	Total (in lbs.)	Avg. Per Angler	Total (in lbs.)	Avg. Per Angler
11,572,953	68	3,179,290	18	5,517,752	32	4,553,255	27

Anglers fish over 2.2 million days annually, with resident anglers accounting for 88% of the total. Most of the angling occurs in southern Manitoba, especially along the Red River and the Whiteshell/Nopiming region. The 2000 preliminary study results indicate that approximately 14 million fish are caught and about 3.4 million are kept (Wall 2002). On average, anglers catch four fish per day.

Environment Canada estimates that residents of Manitoba spent $339.4 million (US) on nature-related activities during 1996, including outdoor activities in natural areas, wildlife viewing, recreational fishing, and hunting (mammals, waterfowl, birds, and other). Almost 30% of those expenditures were for recreational fishing, with the average resident spending $579 (US) annually, or $33 per day of participation. Additional expenditures for equipment (38%), transportation (22%), food (19%), accommodations (11%), and other costs (5%) were also noted. The remaining 5% was spent on contributions to nature-related organizations.

Nature-related expenditures in Manitoba contributed over $322 million to the provincial gross domestic product (GDP), and supported 8,700 local jobs in 1996. Local and provincial government received $113 million in revenue from diverse taxes. Residents of Manitoba derived significant economic value from their participation in recreational fishing, as well. The average economic value of recreational fishing per participant was $98 annually and $11.60 daily.

The total direct and indirect annual value of the Lake Winnipeg and Red River commercial and sport fishery to the Manitoba economy is approximately $31 million (US). Manitoba’s commercial fishery produces 33% of the total value of Canada’s freshwater commercial harvest. Commercial fishing affects the local economies of many small communities and the industry employs approximately 3,200 people in the province. Since 1986, the annual commercial harvest has averaged about 26.6 million pounds per year. This represents nearly $15.3 million (US dollars) a year that is invested back into Manitoba’s economy.

Whitefish (23%), mullet (23%), walleye ("pickerel" locally) (20%), northern pike (11%) and sauger (10%) are the major species commercially harvested in Manitoba. Of these species, walleye accounts for 47% of the landed value paid directly to commercial fishermen, due to its high market price. Sauger and whitefish represent 20% and 14% of the landed value, respectively.

The Lake Winnipeg fishery accounts for approximately 50% of the total commercial fish harvest from Manitoba. Each year, approximately 800 licensed commercial fishers operate on Lake Winnipeg, catching a variety of species, including walleye, goldeye, sauger, and whitefish. Commercial fishers also directly employ another 150 persons to assist with fishing operations. The annual direct value of the landed catch is approximately \$9.4 million (US). For many involved in the commercial fishing sector, this is their only source of income.

Harvests of walleye and sauger on Lake Winnipeg are declining, but not due to a lack of effort by fishermen. The declines follow periods of high production, indicating that stocks are being exploited at, or beyond, sustainable harvest levels. Quotas have been redefined to better reflect sustainable harvest levels for these fish. The walleye and sauger harvest has been capped at 20% of existing quotas. In addition, season openings have been set by lake area to follow completion of walleye spawning. Also, the Lake Manitoba small mesh fishery for perch is reviewed annually to determine its impacts on walleye and sauger stocks.

Landed fish are sold through the Freshwater Fish Marketing Corporation (FFMC), which serves fishermen in Manitoba, Saskatchewan, Alberta, Northwest Territories, and part of Northwestern Ontario. Fish are then shipped to packing stations throughout Manitoba by air, water and/or land. On average, Manitoba commercial fishermen catch approximately 64% of all the fish sold to FFMC, and receive 75% of the total landed value. Fish are sold in American markets, overseas countries, and directly to final consumers.

Domestic fishing is fishing for food by Treaty Indian persons and by individuals who legitimately require access to the fisheries resource to meet basic subsistence requirements. Domestic fishing has long been an important activity to First Nations peoples. Fish have, and continue to be a valuable source of food. Fishing also plays an important role in bringing people together socially, including the celebration of religious and cultural traditions.

Treaties were signed in the late 1800s and early 1900s between Canada and First Nation representatives. These treaties protected, among other things, the right of Status Indians to fish for food during any time of the year. In 1990, the Supreme Court of Canada issued a landmark ruling in the *Sparrow* decision. This decision defined Aboriginal peoples' right to fish for food, social and ceremonial purposes. This right takes priority over all other uses of the fishery, subject to certain overriding considerations such as conservation of the resource. The Supreme Court also necessitated consultations with Aboriginal groups when their fishing rights might be affected.

In Manitoba, fish stock conservation to ensure resource sustainability is the first priority for making fishery management decisions. Following this, domestic fishing for food by First Nations peoples is given the highest priority for harvest of the fishery resource. Historically, the provincial government of Manitoba interpreted permitting requirements for domestic fisheries to be an infringement of the fishing rights of First Nations peoples, unless there was an overriding fishery conservation issue. Although this interpretation has changed slightly in the past few years, there is no current permitting requirement for the domestic fishery. Therefore, Manitoba Conservation, Fisheries Division, has very little data regarding the size, composition and economic value of the annual domestic fishery harvest.

Over 23,000 permanent residents living in 30 communities along the shore of Lake Winnipeg depend upon the lake's fishery as a food source. The majority of these residents are Aboriginal with over 9,000 being First Nations. The most active First Nations bands fishing Lake Winnipeg are: Grand Rapids (November 2001 registered population 1,250), Fisher River (2,932), Poplar River First Nation (1,161), Berens River (2,279), Hollow Water (1,289), Dauphin River (242), Lake St. Martin (1,847) and Norway House Cree Nation (1996 population – 3,402), (Swanson, 2001 and Statistics Canada). A rare 1980-1981 survey of the domestic fish harvest in the community of Cross Lake (1996 population – 1,529), located on the Nelson River in northern Manitoba, indicated that over 227,000 pounds of fish were caught in one year. Over half of this harvest was fish species popular for eating. If this food had been purchased in the local grocery store, the estimated cost would have been over $103,000 (US). Fish commonly sought by current domestic fishers are walleye, whitefish, and some sturgeon in the southeastern parts of Lake Winnipeg. Traditionally, whitefish for food and mullet for dog food were the most sought-after fish (Swanson, 2001).

3.7.3.4 Socioeconomic implications of striped bass introduction.

Striped bass potentially released from Devils Lake are not expected to survive in the riverine habitats of the Red River. Only large stratified lakes can support striped bass; therefore, this analysis examines only the potential impact of striped bass in Lake Winnipeg and Lake Ashtabula. However, both lakes are much further north than any other lake or reservoir that supports a striped bass population. The risk associated with striped bass establishing a spawning population in Lake Ashtabula or Lake Winnipeg is extremely low for reasons described above.

The following information summarizes *potential* effects in the unlikely event that striped bass do enter the Lake Winnipeg or Lake Ashtabula fishery and establish a spawning population. If only a few specimens of mature striped bass exist in Devils Lake as suspected, and those mature fish were to arrive in either lake, they are not expected to have any notable impact on the fishery because they are not expected to spawn.

While a remote possibility, a healthy, reproducing population of striped bass in Lake Winnipeg could have an effect on both the fishery and, consequently, the domestic, commercial and recreational fishermen who use the lake. Socioeconomic impacts on the fishery and fishermen would be expected to include both positive and negative effects. Although tourism is an important industry in Manitoba, the introduction of striped bass is not expected to impact non-fishing-related tourism in any significant manner. Striped bass in the lakes are not anticipated to have any impact on other forms of active or passive recreation such as canoeing, swimming, biking, camping, or hunting.

The most significant ecological impact of the introduction of striped bass in other lakes and reservoirs has been the reduction of pelagic (i.e., open water) clupeid species such as alewife. However, neither Lake Ashtabula nor Lake Winnipeg contains any clupeid species. Potential striped bass prey in open water habitats of Lake Winnipeg could include goldeye, cisco, lake whitefish, other coregonids, and cyprinid species that inhabit open waters. In addition, striped bass are likely to prey upon small fish that concentrate in near shore habitats for spawning or other seasonal movement. Striped bass could compete with other fish species that rely on small fish as their primary prey. In particular, competition may occur between striped bass and lake trout or walleye, two important recreational species in Lake Winnipeg. Striped bass and walleye could compete for food on Lake Ashtabula. Competition among lake trout, walleye, and striped bass could potentially reduce the lake trout and walleye fishery, which could have a negative impact on recreational fishing expenditures by anglers specifically targeting those species. However, even if this occurred, the recreational impacts would likely be offset by increased fishing for striped bass. Striped bass are a very popular game fish due to their large size, fighting ability when hooked, and quality as a food fish. If striped bass became established in Lake Winnipeg, the increasing popularity of striped bass fishing and the lack of striped bass fisheries in Canada could make Lake Winnipeg a popular and valuable fishery for this species.

The Marine Recreational Fisheries Statistics Survey, administered by the National Marine Fisheries Service, estimated that sportfishing trips for striped bass (in the United States) increased from 247,000 trips in 1990 to 691,000 in 1997. A striped bass fishery in Lake Winnipeg or Lake Ashtabula could induce additional recreational angling and, consequently, additional expenditures associated with recreational fishing, including equipment, accommodations, food, transportation and permits. A disproportionate percentage of the expenditures would be for transportation as anglers travel from greater distances to take advantage of the striped bass fishery. Several uncertainties exist regarding the possible size and health of a striped bass fishery in either Lake Winnipeg or Lake Ashtabula because all data indicate that the striped bass will not reproduce in these habitats. Therefore, potential impacts cannot be quantified; however, adverse socioeconomic impacts are not expected to accrue.

Commercial fishing on Lake Winnipeg plays a crucial role in Manitoba's economy. Introduction of a spawning population of striped bass in Lake Winnipeg would be expected to have impacts similar to those in the recreational fishing sector. However, reductions in the populations of commercially important fish species in demand by consumers could have negative ramifications within the commercial fishing industry. These negative effects may not be offset by the availability of striped bass in Lake Winnipeg because the product is available through other commercial markets.

Again, quantification of impacts is not possible because available information indicates that striped bass will not reproduce in Lake Winnipeg or Lake Ashtabula. Therefore, biologists are unable to state with any certainty how quickly a population could become established and what the expected population size might be within the study period. Negative socioeconomic impacts to the commercial fishing industry may be expected to accrue in the unlikely event that a spawning striped bass population is established in Lake Winnipeg.

Due to the lack of information regarding the size, composition and economic value of the annual domestic fishery harvest on Lake Winnipeg, impacts from the introduction of striped bass are likewise unquantifiable. Presumably, impacts would be similar to those expected for the commercial and recreational fisheries, including a reduction in whitefish, a possible reduction in walleye and lake trout, and a simultaneous increase in striped bass. Striped bass are a particularly good fish for human consumption, so changes in fishery composition would not be expected to substantially impact the diet of Aboriginal people who fish Lake Winnipeg for subsistence. However, because the Aboriginal people are more likely to use all parts of harvested fish for various purposes, a change in the composition of the fishery could have some impact on their way of life, including cultural and religious observations.

3.7.4 Risk Characterization

This characterization follows the procedures for federal government ecological risk assessments presented in the nonindigenous species example in Chapter 4 of CENR (1999). It assigns qualitative likelihood and certainty ratings to specific items regarding probability and effects of striped bass invasion. Certainty ratings represent qualitative estimates of the certainty of the ascribed probabilities.

No Build, No Natural Spill Alternative

If no outlet is built, there would be no risk of transfer of striped bass to the Sheyenne/Red River system, except by illegal stocking, as described above. This risk exists and is relatively low at present, and this would persist under all scenarios.

Constructed Outlet, 300 cfs Constrained and 480 cfs Unconstrained Operational Alternatives

1. Estimate probability of the exotic organism being on the potential transfer pathway:

   Negligible to low probability – moderately certain. The species may no longer occur in Devils Lake. If it does, it is probably represented only by a small number of large adults because suitable spawning habitat appears to be absent, and successful reproduction of introduced striped bass populations is very uncommon.

2. Estimate probability of the organism surviving in transit:

   Low probability – very certain. Adult individuals would not be transferred but some larvae and juveniles could survive the pump works. The probability of any single individual surviving transfer to Lake Ashtabula and further surviving to reproductive age would be negligible. Considerable mortality would be expected in transit through pumps, ponds, and the Sheyenne River, as well as in Lake Ashtabula, because mortality of young fish is generally high due to predation, accident, and poor fitness, and these individuals would also be subjected to multiple stresses and unfamiliar environmental conditions (e.g. streamflow).

3. Estimate probability of the organism successfully establishing a population if introduced:

   Very low probability – moderately certain. Given the expected high juvenile mortality described above, a large number of individuals would have to be entrained in the outlet works to ensure sufficient numbers would survive transfer to Lake Ashtabula and survive to reproductive age in the lake. If larval and/or juvenile fish are produced in Devils Lake and consistently occur near the pump intakes (very unlikely occurrences), and assuming continuous operation of an outlet for seven months of each of several years, it is possible that eventually enough individuals could be transferred to Lake Ashtabula to establish a population. A reproductive population would require spawning habitat, which appears to be absent (although if the species can spawn in Devils Lake, it could probably also spawn in Lake Ashtabula), but a non-reproductive population could be established as long as the outlet would continue to provide fresh immigrants to the lake. Under this scenario, the population would eventually disappear after the outlet discontinues operation. However, as long as some striped bass occur in Lake Ashtabula, further downstream transfer of individuals of all ages would be possible (large fish could wash over the dam spillway under high water conditions). Transit from the dam to Lake Winnipeg would be very hazardous for juveniles, but less so for large adults. While the likelihood of suitable spawning habitat occurring in Lake Ashtabula is remote, the likelihood is much greater for Lake Winnipeg. However, colonization of Lake Ashtabula is considered a prerequisite to further downstream spread, so invasion of Lake Winnipeg is even less likely than Lake Ashtabula colonization.

4. Estimate probability of the organisms to spread beyond the colonized area:

   Moderate to high probability – moderately certain. If a reproducing population could become established in Lake Ashtabula, it could spread downstream with relative ease because the lake would serve as an indefinite source of individuals of all sizes. The journey downstream to Lake Winnipeg would be hazardous for juveniles, but adult individuals could would have good chances of surviving the trip. Lake Winnipeg would provide spawning habitat, though it would probably be only marginally suitable in low-runoff years. If established in Lake Winnipeg, the species could spread further through tributaries and downstream, if suitable habitat is found in those areas.

5. Estimate economic impact if established:

   Low net impact – moderately certain. Wherever introduced, striped bass displace some native fishes, though rarely eliminate them from communities. Economically important species in Lake Winnipeg have not been known to be dramatically affected by striped bass introductions in other places. Economic costs due to lost production of native fish would likely be offset by benefits resulting from the popularity of striped bass as a game fish. However, this suggests that some economic value of the lake's fishery would shift from commercial to recreational fishing.

6. Estimate environmental impact if established:

   Low impact – moderately certain. Composition of the Lake Winnipeg fish community is not fully known, but striped bass would likely displace some native piscivores (individuals, probably not populations). They would take over the food web roles of these fishes, so cascading effects are unlikely. No other ecological impacts would be likely.

7. Estimate impact from social and/or political influences:

   Moderate impact – moderately certain. Government agencies in affected jurisdictions are very concerned about the introduction of the species. Infestation of downstream waters would create or increase interstate (North Dakota-Minnesota) and international (US-Canada) tensions, and possibly internal political tensions. Public reaction to striped bass invasion would likely be mixed, with anglers and angling-related businesses in favor, and environmental concerns opposed.

OVERALL RISK: The risk of downstream striped bass spread is extremely low under any outlet alternative because the species is not believed to be reproducing in Devils Lake. Thus individuals of a size that could be transferred through an outlet, or via bait buckets, are highly unlikely to exist in the lake. However, if larval and juvenile striped bass occur in Devils Lake, the proposed outlet would create a pathway for transfer to the Sheyenne River. Risks would be the same under both constructed outlet scenarios, except that the higher flow-rate with the 480 cfs unconstrained outlet alternative would incrementally increase the probability of more individuals being transferred in a given time period, thus proportionally increasing the overall risk and potential speed of transfer. Either alternative would likely create a very small risk of striped bass establishment in Lake Ashtabula and an even smaller risk of establishment in Lake Winnipeg.

<u>No Build, Natural Spill Alternative</u>

The individual assessments of risk under this scenario are the same as that for the constructed outlet scenarios above, except items 1 through 3:

1. Estimate probability of the exotic organism being on the potential transfer pathway:

   Low probability – uncertain. This would be very similar to constructed outlet scenarios: it is doubtful that the species reproduces in Devils Lake, and it may not even exist there. However, it is remotely possible that the successive years of high precipitation and resulting influxes to Devils Lake assumed under this alternative will improve spawning habitat suitability, providing reproductive opportunities that could grow the population available for transfer.

2. Estimate probability of the organism surviving in transit:

   Moderate probability (high for adult fish, low for juveniles) – moderately certain. In this situation, any striped bass present in Devils/Stump Lake could become entrained in overflow water if they wander near enough to the spill location. This would be most likely to occur during non-stratified conditions (i.e., spring or fall), because adult striped bass would likely avoid warm surface water in summer and cold surface water in winter. Spillage would be most likely to occur in spring, when lake level is typically highest as a result of spring runoff. Because the Sheyenne River also normally runs high at this time of year, any spilled striped bass would be more likely to be swept fairly quickly down to Lake Ashtabula. Probability of individual survival for larvae and juveniles would be somewhat higher than under constructed outlet scenarios, but, more important, adults could be transferred under this scenario. Further, no individuals would be subjected to the hazards and stress of passing through pump works. Fish entrained in spill water would enter the Sheyenne River substantially closer to Lake Ashtabula than under constructed outlet scenarios. Entry at the Stump Lake spill site would occur at roughly half the distance from the Peterson Coulee mouth to Lake Ashtabula.

3. Estimate probability of the organism successfully establishing a population if introduced:

   Low to moderate probability – moderately certain. The potential transfer of adult fish, as well as the higher probability of individual survival described above, would increase the probability of population establishment in Lake Ashtabula, especially if the wet cycle continues, causing ongoing spillage from Stump Lake. The likelihood of the fish finding suitable spawning habitat in Lake Ashtabula would remain very low, but the possibility of adult fish moving downstream to Lake Winnipeg and spawning would pose a non-trivial risk of invasion.

OVERALL RISK: If no outlet is built and Devils Lake eventually overflows through Stump Lake, the risk of downstream transfer of striped bass would be higher than under either constructed outlet scenario, primarily because a natural overflow would allow adult individuals to disperse downstream. This could allow surviving adults from the original 1977 stock to move downstream, possibly finding spawning habitat in Lake Ashtabula (though unlikely) or Lake Winnipeg. In other words, this scenario could obviate the need for reproduction in Devils Lake as a prerequisite for spread, creating a qualitatively more substantial threat of spread than under constructed outlet scenarios.

3.7.5 Risk Management

Existing mechanisms for managing risks of invasive species introductions in North Dakota are few. No North Dakota laws or regulations specific to invasive, or non-native, fish were documented during this evaluation. Stocking fish in North Dakota waters requires a permit. The state of North Dakota has no future plans for stocking striped bass. Presumably, any live adult striped bass that anglers might remove from Devils Lake could not be legally stocked in other waters.

The National Invasive Species Management Plan recommends actions in nine categories: leadership and coordination, prevention, early detection and rapid response, control and management, restoration, international cooperation, research, information management, and education and public awareness. The Plan also notes the importance of monitoring. The U.S. Army Corps of Engineers is among the federal agencies charged with implementing the Plan. By definition, the EIS addresses many aspects of the Plan. Specifically, information has been summarized to identify invasive species (early detection and response), control and management options are being evaluated, and international issues are being addressed. Because striped bass may already be present in Devils Lake, the control and management aspects of the Plan are most relevant at this time. The assessment of feasibility and costs and benefits of the outlet proposal must include provisions for screening striped bass from the discharge. In addition, future operations should include monitoring of the intake or discharge for the presence of striped bass. The Presidential Executive Order 13112 on Invasive Species provides definitions and guidance for the development of specific measures to control invasive plants and animals. The Order makes specific reference to the more detailed National Invasive Species Management Plan. As such, USACE compliance with provisions of the National Invasive Species Management Plan, would appear to constitute compliance with the Order.

One management option under consideration is to forego building a Devils Lake outlet. This would result in one of two scenarios: lake levels would rise until the natural overflow elevation is reached, and water would spill from Stump Lake to the Sheyenne River, or the wet cycle would end before the overflow level is reached. In the latter case, there would be no additional risk of striped bass transfer over that which exists at present. In the former case, risk of striped bass transfer would be substantial (if the species exists in Devils Lake), so screening methods would be advisable. Standard fish screens, such as those proposed for use at the outlet intakes, would suffice to prevent adult fish entering the spillway, but larval and juvenile transfer would be difficult to prevent without a constructed spillway that would allow flow control and screening mechanisms, as described below.

Project managers could choose from a few well-tested methods to prevent the spread of larval, juvenile and adult striped bass through a constructed outlet. Adult striped bass, and large fish in general, have a very low probability of entrainment for several reasons. The probability of a large fish encountering the pump station is very low, relative to juvenile fish, due to the simple fact that there are far more juvenile fish in a typical population. More importantly, adult fish can easily detect and avoid the flow field and structures surrounding a pump facility. Screening options for large fish are relatively cheap, reliable, and have little operational impact: The pumping station would be equipped with coarse bar racks (e.g., 4 to 6 inch clear spacing) or other screening to protect the pumps from debris and potential damage. This coarse screening would prevent adult striped bass from being entrained in the pumps.

Larval and juvenile fish are at greater risk of entrainment in pumps. If striped bass have reproduced in Devils Lake, then larval or juvenile striped bass could be entrained. Several options exist for screening these small life stages. Experience from irrigation and water diversions provides several proven technologies. Traveling screens (horizontal or vertical), rotating drum screens, and wedge wire screens are routinely used to screen fish from water diversions (Bell 1991). These technologies share several features. They are all installed in open channels and require a minimum of several feet of head to operate. Each can operate with screening as small as approximately 1/8 inch, a size that would easily prevent the passage of larval striped bass. Perhaps the most important shared feature is the ability to operate with debris loads, a shortcoming of most static screen approaches. The rotating drum and traveling screen designs are similar in that a mesh structure rotates, or travels through a channel, to a washing station where spray bars wash debris and impinged fish from the screen. Of these two approaches, the rotating drum design is more commonly used, with hundreds of facilities throughout the western United States. Wedge wire screening facilities are also able to deal with debris loads. However, the wedge wire design differs in that the wedge shape of the horizontal screen elements shear the water to the underside of the screen while passing debris over the top. All of these screening designs are typically installed in situations where fish must be guided and diverted, as opposed to impinged on the structures and injured or killed, since the goal is to separate fish from diverted water and return them to the parent stream in good condition. A suitable open channel location in the proposed Devils Lake diversion might have to be located some distance from the lake. Thus, it could be difficult to return diverted fish to the lake.

Traveling screens, rotating drum screens, and wedge wire screens all have high capital and operating costs. Each of these designs requires a supporting concrete structure across the entire channel. Traveling screens and rotating drum screens require electrical service which increases the construction and operating costs. Each of these designs requires staffing and frequent attention. Debris must be trucked and landfilled. Depending on site characteristics and the design flow for operations, capital costs could be millions of dollars. Operating costs might be as high as several hundred thousand dollars annually.

3.8 Risk Assessment: Eurasian watermilfoil (*Myriophyllum spicatum*)

While the assessment conducted for vascular plants failed to identify any species of concern within the Devil's Lake basin, a small population of the highly invasive aquatic species Eurasian watermilfoil (EWM) had been observed in a backwater of the Sheyenne River in 1996. There is a risk that the increased flows associated with the proposed Devils Lake discharge could facilitate the spread of this noxious weed throughout the Red River channel in both the United States and into Canada, particularly into Lake Winnipeg, Manitoba. This document assesses the risk of the migration of this species into the Red River channel and to Lake Winnipeg under the present conditions and under the two constructed-outlet scenarios.

The Sheyenne River EWM population was first found in September of 1996 in a backwater area of the river in Valley City, ND. The plants occurred over a $150m^2$ area, with scattered individuals up to 70m downstream. A complete description of the sighting is in Alexander (1998). The population apparently disappeared after the following winter, an occurrence attributed to a drawdown of the river which allowed substrate freezing. However, the plant was found in the same location again in 2001 (T. Steinwand, pers. comm.). Basic life history and other biological/ecological information about EWM are described in Section 3.6.1.2 above. Under the constrained outlet alternative, the outlet would deliver Devils Lake water to the Sheyenne River channel via Peterson Coulee, at a point about 8 miles west of the town of Oberon, at a maximum rate of 300 cfs during high flow periods (May) and about 150 cfs during low flow periods (August), and under the unconstrained alternative, the maximum discharge rate during high flow periods would be 480 cfs. This discharge would not directly affect the existing EWM population, which is below Baldhill Dam, but would necessitate higher discharge levels from the dam to prevent excessive water level rise in Lake Ashtabula. These altered discharges could increase the likelihood and/or speed of downstream EWM transport.

3.8.1 Characterization of Exposure

"Exposure" refers to the introduction of a sufficient number of EWM fragments such that some would land by chance in suitable habitat and on a substrate type conducive to growth. Once growth begins, it is likely that a clonal colony would become established, so continued introductions from upstream would be unnecessary to maintain the population, although they could cause new colonies to become established.

3.8.1.1 EWM habitats and invasiveness.

The history of EWM invasion in North America and habitats invaded are described in Section 3.6.1.2 above. The plant is considered highly invasive and relatively plastic in habitat preference. It has been found growing in a variety of trophic, pH, salinity, temperature, and other lake conditions, though it is most common in mesotrophic to moderately eutrophic lakes (Madsen 1998). Like many invasive species, it is especially aggressive in disturbed environments, where native community stability has been disrupted. Many have noted the plant thriving in mildly eutrophic lakes, but this may be more a response to disturbance than to nutrient levels in particular. The species does not grow aggressively in all waters (e.g the Great Lakes), but factors determining whether EWM grows to nuisance levels have not been determined (Smith and Barko 1990).

3.8.1.2 Potential for EWM reproduction in Red River basin waters and Lake Winnipeg.

EWM reproduction is prolific because it uses primarily vegetative means not requiring sexual processes to originate new individuals and colonies. Sexual reproduction does, however, occur regularly, providing an adaptive reproduction method that can withstand disturbances such as drought (Standifer and Madsen 1997). However, during a typical growing season, existing plants autofragment, and new colonies are formed when fragments drift and settle on suitable substrates. Local vegetative growth usually occurs via stolons, which grow laterally over the substrate, sometimes growing roots at nodes and separating from the parent plant (Madsen and Smith 1997). Thus most "patches" of the species are really clonal colonies. Through these vegetative means, EWM can travel considerable distances and colonies can form from the smallest toe-holds. Downstream drift of propagules can be an important mode of colonization for submergent aquatic plants (Andersson et al. 2000, Henry and Amoros 1996), so habitats downstream from the existing Sheyenne River EWM population are very vulnerable to infestation. In fact, downstream movement and infestation appears almost inevitable if no action is taken very soon, whether an outlet is built or not. If the plant were to invade Lake Winnipeg, it could relatively quickly colonize appropriate habitat throughout the lake. In Lake George, NY, EWM colonization was first noted at one site in 1985, and by 1993, 106 discrete locations had been infested (Boylens et al. 1994). On the other hand, the plant does not become a competetive dominant in all systems, for unknown reasons, so its growth and invasiveness in the Red River basin and Lake Winnipeg cannot be predicted.

3.8.1.3 Downstream habitats potentially affected.

EWM would find much suitable habitat downstream of Valley City, but would be limited by streamflow, depth, and wave energy. Shallow, nutrient-rich fine sediments are best for colonization from fragments (Kimbel 1982). As apparently occurred in the Detroit River system (Schloesser and Manny 1984), the plant could invade any suitable habitats downstream from the source population. Any parts of the Sheyenne and Red Rivers that are slow enough to have fine sediments and allow rooting would be vulnerable to colonization. This would include any backwaters, shallow-sloped submerged banks off the main channel, pools, and inner banks of meanders. It would also find suitable habitat in protected areas of the littoral zone of Lake Winnipeg; wave-swept shorelines generally preclude establishment of rooted submergent plants like EWM. Like many submergents, this plant can be somewhat limited by turbidity, but the existing population is growing in turbid water, showing the adaptability of the species. In turbid water, light doesn't penetrate far below the surface, so the plant forms dense floating mats just below the surface where light is available.

3.8.1.4 Potential mechanisms for transfer under outlet scenarios.

Rates of fragmentation and fragment transport under different streamflow regimes cannot be quantified. It is clear that the existing population already has the potential to spread downstream under present conditions, but how soon this could happen (or may already have happened) cannot be predicted with any degree of certainty. If further infestations have not already begun, it would seem to be only a matter of time. If the existing colony expands it should eventually come in contact with the main channel, making entrainment of fragments nearly certain. The occurrence of a few individuals downstream from the main population suggests that downstream spread had already begun before the 1996-97 winter seemingly eradicated the population. It is likely that this spread will recur, and that the plant may be able to spread by short "jumps" from point to point downstream. Longer jumps may also be possible, but estimates of how long fragments can survive in a free-floating state are not available. Several studies have determined downstream drift rates for a variety of materials, such as woody debris (Jacobson et al. 1999), insects (Allan and Feifarek 1989), and fish eggs (Engel 1995). However, drift rates vary depending on flow rates and the objects' shapes, sizes and buoyancies. A more thorough literature review on streamflow dynamics, combined with streamflow modeling and empirical tests, would be necessary to estimate EWM drift rates in the Sheyenne/Red River system with a reasonable degree of reliability. As a conservative estimate, it should be assumed that fragments could perhaps survive the entire trip down river to Lake Winnipeg, especially during spring when flow rates are highest. Given this assumption, it must be also assumed that any increase in flow rates and duration precipitated by an outlet project would increase the likelihood of EWM fragment transport over longer distances in any given time period. However, it would not likely increase the probability that EWM will eventually spread downstream, but only would speed up the process by an unknown factor. The ultimate probability of spread appears to be 100%, given enough time.

There are some additional ways that high flows due to an outlet could enhance the rate of EWM spread. First, higher river stage could flood more adjacent low areas, creating more still backwaters where EWM could become established. Second, higher sustained levels could increase recreational boating use of the rivers, increasing the likelihood of human-mediated spread. Finally, higher levels could also encourage increased use of river backwaters by waterfowl, another suspected vector of EWM fragments.

3.8.2 Characterization of Ecological Effects

EWM is a superior competitor as compared to most indigenous species under a variety of conditions. Colonies grow aggressively, shading other species and suppressing their growth (Madsen et al. 1991) and diversity (Boylen et al 1994). Plant community diversity is often reduced, and the resulting reduction in microhabitat diversity causes animal communities to decline also. Invertebrate productivity may not suffer, or may even increase, but diversity decreases, resulting in fewer types of food resources for fish and birds. Also, EWM can change the limnological conditions by causing water stagnation and consequent decline in dissolved oxygen. This, combined with high structural density, can make EWM stands unsuitable habitat for fish and some invertebrates.

In some situations, EWM's aggressive growth capabilities allow it to become established where no other submergent species were able to survive. In such cases, habitat for fish and invertebrates can be created where none existed, so fishing conditions may improve (Engel 1995, Keast 1984).

It is not possible to predict how EWM would affect Lake Ashtabula, the Red River, or Lake Winnipeg because key limiting factors and determinants of infestation are still not known. Further, little information on existing ecological conditions in these waters were available for this report. Conservatively, it may be prudent to assume that the plant would readily infest any shallow, wave-protected shoreline areas in these water bodies. If this occurs, much biotic diversity and desirable habitat could be lost.

3.8.3 Characterization of Socioeconomic effects

3.8.3.1 Existing conditions on Lake Ashtabula, Red River of the North, and Lake Winnipeg.

See descriptions in the striped bass risk assessment above.

3.8.3.2 Socioeconomic implications of Eurasian watermilfoil introduction.

EWM in Lake Ashtabula and Lake Winnipeg could negatively affect a large number of anglers, boaters, canoeists, and other recreationists (both active and passive), especially if new populations are left uncontrolled. EWM is not expected to substantielly impact angling along the Red River because the species has a fairly low probability of establishment in flowing stream reaches. In fact, it could create some new fish habitat in the river. The socioeconomic implications associated with each of these recreation impacts on regional waterways are discussed below, as well as other economic impacts that may occur as a result of ecological changes associated with EWM.

Lakeshore anglers may enjoy an increase in protective habitat for young fish and bass (Aiken et al. 1979) as the EWM colonizes the nearshore area; however, retrieving fishing gear, including lures and line, from the infested areas without losing gear and fish, or ripping theEWM into additional viable plant pieces could prove frustrating. Over the long-term, may restrict fish habitat and food sources and reduce the number and availability of sport fish. Boaters in EWM-infested areas would become subject to additional restrictions when transferring a boat between basins, and boating anglers may experience the same effects as the shore anglers when fishing lines become trapped in the EWM mats, especially while trolling. Boat propellers chewing the EWM into additional pieces could increase the speed of the EWM's spread by sending additional propagules downstream. If EWM becomes lodged in the water intake lines of boat engines, the engine cooling process is disrupted and the engines may malfunction or seize, resulting in equipment damages and additional operating costs for boaters and boat anglers. Mature plants can become entangled in the propeller causing the engine to stop running, as well. As an invasive non-native species, EWM may crowd out native aquatic vegetation in select areas. Where it overcomes natural communities, habitat diversity would be reduced, negatively affecting habitat for fish and waterfowl, thus affecting fishing and hunting. However, if EWM grows where no submergent plants were present, it would increase habitat for these animals, thus improving recreational resources.

Canoeists and other boaters would be less likely to traverse any river, stream, or lake infested with EWM. The dense EWM mats would hamper progress while paddling the waterways and decrease the aesthetic appeal of boating. Decaying mats can foul lakeside beaches, while water skiing and swimming through the dense mats can be an unpleasant and dangerous experience, especially if trash and debris are caught in the mats. Infestations have an impact on the recreational use of waterways through increased risk to swimmers and problems of swimmers itch. Milfoil has been implicated in several drownings throughout the United States, when swimmers become entangled in the underwater weed mass. Public safety concerns and costs to monitor or post danger signs in swimming areas could become economic factors for local governments.

Passive recreation at or near the lakes would be impacted by the reduced aesthetic appeal of EWM-infestations. Lake users see a flat, yellow-green mass of matted vegetation, often prompting the perception that the lake is "infested" or "dead". Again, if trash and debris are caught in the EWM mats and unpleasant odors are associated with stagnant backwater areas, hiking/walking/jogging, biking, pleasure driving, picnicking, as well as fishing and hunting, may be negatively affected if those activities are normally undertaken near the banks of waterways.

In addition to recreation impacts, EWM infestations can: reduce aesthetic desirability of infested water bodies, result in lowered dissolved oxygen levels (possibly causing fish kills and odors), and cause significant increases in mosquitoes. Milfoil can clog water intakes for industrial plants, electric power plants and irrigation systems, but no municipal or industrial water intakes are known to be operating on Lake Winnipeg. However, within Manitoba alone, the Red River is used as a direct source of potable water for approximately 40,000 residents.

The considerable expense related to EWM control is another important economic impact that affects management authorities, local governments and indirectly affects taxpayers. A general rule is that herbicide treatments in still water cost approximately $300 per acre (C. Welling, pers. comm.). Mechanical harvesting costs vary widely based on transportation costs of equipment and disposal of harvested weeds. Costs of ongoing management can run high, costing approximately $1 million (US) in New York, Washington, Wisconsin, Vermont, and British Columbia (Canada).

However, there are also some potential beneficial economic attributes associated with EWM that may offset some of the expenses. In some cases, harvested EWM has been used to fertilize plants (Anderson et al. 1965), feed animals (Muztar 1976; Muztar et al. 1976) and condition soil (Wile et al. 1978). Also, as mentioned above, the species can create new fish habitat in some situations.

Quantification of economic impacts in the potential impact regions for each of the factors described above would require a detailed geographic probability assessment for EWM establishment. The species is known to have a low probability of establishment in flowing stream sections; therefore, such a detailed assessment would require extensive data about the location, size, shape, and water quality characteristics of backwater areas on the Sheyenne and Red Rivers under water level regimes associated with a Devils Lake outlet. Additional detailed knowledge about the habits of active and passive recreationists in the region (especially anglers and boaters) would also be necessary to determine whether they would relocate to areas not infested with EWM.

3.8.4 Risk Characterization

This characterization follows the procedures for federal government ecological risk assessments presented in the nonindigenous species example in Chapter 4 of CENR (1999). It assigns qualitative likelihood and certainty ratings to specific items regarding probability and effects of EWM invasion. Certainty ratings represent a qualitative estimate of the certainty of the ascribed probability.

No build, No Natural Spill Alternative (Existing Conditions)

1. Estimate probability of the exotic organism being on the potential transfer pathway:

   High probability – very certain. The species is known to occur within the river system and is likely to be carried downstream in time.

2. Estimate probability of the organism surviving in transit:

   High probability – very certain. Pathways for EWM to suitable downstream habitats is available, unobstructed, and favorable to survival. A small degree of short-distance spread has already been shown by the population. However, for longer-distance transit in single "jumps", survival probability is probably lower and is less certain.

3. Estimate probability of the organism successfully colonizing and maintaining a population where introduced:

   Moderate probability – moderately certain. Downstream habitat conditions appear favorable for the species, but enough fragments would have to be transported such that some would settle in backwater and other slow areas sheltered from the main channel or in structure (e.g. woody debris) in or adjacent to the channel. If this did not occur, fragments would have to be transported the full distance to Lake Winnipeg. Ultimate success of colonization in any of these habitats is speculative, especially because the effects of biotic interactions at the higher latitudes of Lake Winnipeg cannot be fully predicted.

4. Estimate probability of the organism to spread beyond the colonized area:

   High probability – moderately uncertain. Assuming the species can colonize downstream river habitats, it would be expected to continue to spread to other river habitats and to Lake Winnipeg. Further assuming that the species becomes established in Lake Winnipeg, it would have a fairly high probability of spreading. This species tends to proliferate where it invades, especially in shallow, warm, moderately eutrophic lakes like Lake Winnipeg. However, certainty of this assessment is moderate because it is unknown what factors cause aggressive proliferation.

5. Estimate economic impact if established:

   Moderate to high impact – uncertain. Assuming aggressive infestation, aesthetic and recreational value of the affected areas could decrease, negatively affecting tourism. However, fishing habitat in some areas could improve. The value of commercial fisheries is unlikely to be substantially affected. If Lake Winnipeg is infested on a broad scale, it is assumed that lake-wide control measures would be prohibitively costly, so only localized abatement would be attempted. Economic costs would accrue, but their magnitude is uncertain because the choices of local authorities cannot be predicted. Also, it is possible that the species would not become an aggressive invader.

6. Estimate environmental impact if established:

   Moderate to high impact – uncertain. Assuming aggressive infestation, negative effects to indigenous submergent plant diversity and productivity would be high or possibly very high, and probably irreversible. Invertebrate diversity would likely experience localized reductions, and productivity of littoral-dependent game fish species could decline. Localized reductions of dissolved oxygen would make these habitats unsuitable for fishes and many invertebrates. However, overall ecosystem function, total fish and invertebrate diversity and productivity, and emergent plant communities should not be affected. Also, it is possible that the plant would not become an aggressive invader in any of the invaded waters.

7. Estimate impact from social and/or political influences:

Moderate impact – moderately uncertain. Government agencies in affected jurisdictions are very concerned about the introduction of the species. Infestation of downstream waters would create or increase interstate (North Dakota-Minnesota) and international (US-Canada) tensions, and possibly internal political tensions. Only localized riverine colonies would likely occur, but infestation of Lake Winnipeg would probably be regarded by most private citizens as reducing the aesthetic and economic value of Lake Winnipeg, and possibly adding to tax burdens to support control measures. However, only communities on or near the lake would likely be affected. Concern elsewhere is likely to be lower, though concerns about further spread would likely be raised.

OVERALL RISK: The risk of downstream EWM spread is high, and the magnitude of negative effects is moderate to high, under all scenarios. A Devils Lake outlet would not be expected to increase these probabilities or magnitudes, but would likely increase the speed with which infestation would occur.

<u>Constructed Outlet, 300 cfs Constrained and 480 cfs Unconstrained Operational Alternatives</u>

The individual risks associated with a constructed outlet would be the same as under the no-build, no overflow scenario, except items 2 through 4:

2. Estimate probability of the organism surviving in transit:

High probability – very certain. Probability of survival would be even higher than under the above scenario because higher flows would speed downstream movement of fragments, reducing the transit time. The 480 cfs unconstrained outlet alternative would increase flow more than the constrained outlet, increasing survival probability the most.

3. Estimate probability of the organism successfully colonizing and maintaining a population where introduced:

Moderate probability – moderately certain. Under either constructed outlet scenario, downstream colonization probability would remain the same as under the above scenario, but it is likely that colonization would occur sooner, as more fragments would be likely to be carried downstream in shorter time periods. This effect would be greater under the 480 cfs unconstrained outlet alternative than under the 300 cfs constrained outlet.

4. Estimate probability of the organism to spread beyond the colonized area:

High probability – moderately uncertain. As with item 3, probability would likely be the same as under the above scenario, but the speed with which further downstream spread (especially along the Sheyenne River) would occur would likely increase. However, once established in Lake Winnipeg, the higher flows under either outlet scenario would have no effect on EWM spread.

OVERALL RISK: The probability of EWM spread and establishment downstream would remain the same under either outlet scenario as under the no-build, no overflow scenario, but the rate at which spread would occur would probably increase to a degree proportional to the increase in streamflows created.

No Build, Natural Spill Alternative

Risks of EWM spread would be the same under this alternative as under the no-build, no overflow scenario, until the spill from Stump Lake would occur. At that point, the increased flows in the Sheyenne and Red Rivers would augment the potential rate of spread in ways similar to those described under the constructed outlet scenarios above.

3.8.5 Risk Management

Existing mechanisms for managing risks of invasive species introductions in North Dakota are few. No North Dakota laws or regulations specific to invasive, or non-native, aquatic plants were documented during this evaluation. Also, North Dakota is not presently implementing a public information campaign regarding invasive aquatics, as is being done in neighboring Minnesota.

Adopting the no-build, natural spill alternative to a Devils Lake outlet would probably not prevent EWM introduction to downstream habitats. Under this scenario, if a natural spill from Stump Lake should occur before downstream infestation by EWM occurs, then the spill would increase the speed with which the species would spread downstream. However, even if a natural spill doesn't occur, downstream movement of EWM is very likely. The only ways to prevent the spread of the existing population would be to contain and/or eradicate it. The National Invasive Species Management Plan describes actions in nine categories: leadership and coordination, prevention, early detection and rapid response, control and management, restoration, international cooperation, research, information management, and education and public awareness. The state of North Dakota and the US Army Corps of Engineers have been an early detection of an aggressive invasive species. This presents the opportunity for rapid response involving control measures. The Presidential Executive Order 13112 on Invasive Species provides definitions and guidance for the development of specific measures to control invasive plants and animals. The Order makes specific reference to the more detailed National Invasive Species Management Plan.

Many control measures for EWM have been studied, including biocontrol using weevils (Creed and Sheldon 1993) and mechanical harvesting (Painter 1988). However, merely controlling the existing Sheyenne River population would not prevent downstream spread. Because the population is apparently only a localized infestation, the opportunity for complete eradication appears to exist. Triploid (thus, sterile) grass carp could possibly be used to eliminate the existing plants, but this would require penning the carp in the area to ensure that they stay there and eat the EWM. It would also require an impermeable barrier to prevent EWM fragments created by the fish feeding behavior from drifting downstream. EWM is not one of the more preferred food plants for grass carp (Pine and Anderson 1991), so other species within the enclosure could be eaten preferentially until they are gone, at which point the fish would switch to EWM (McKnight and Hepp 1995).

As a more direct and immediate alternative, the existing colony could be physically isolated using aquatic silt fences that could act as fragment barriers, and either mechanical or chemical (or both) eradication methods could be used. Mechanical methods have the disadvantage of fragmenting existing plants in the process of removing them, and may miss parts of a colony. Suction and hand harvesting by SCUBA divers are both effective in keeping EWM in check, but are not generally effective at eradication (Boylen et al. 1994). In the turbid waters of the Sheyenne River, divers would have difficulty locating all plants. Rotovation churns the bottom, removing roots as well as above-ground plant material, but it also creates fragmentation and sedimentation (Gibbons and Gibbons 1998). Thus, chemical eradication may be a more reliable option, but it would also be important to carefully seek any isolated additional plants or young colonies that may occur downstream from the known colony. Only a complete eradication would remove the present risk of downstream spread. Results should be monitored into the future to ensure that a new colony does not start.

If a chemical control option is selected, several herbicides' advantages and disadvantages should be considered. Use of each herbicide is dependent on a number of issues including management objectives, extensiveness of EWM colonies, ecosystem sensitivity, and water flow. Two of the more commonly used herbicides include 2,4-D (2,4-dichlorophenoxyacetic acid) and Triclopyr. 2,4-D is a useful systemic herbicide for controlling EWM and requires a short period of exposure dependent on application concentrations and water movement (Green and Westerdahl 1990). Use of this herbicide can be very beneficial in situations requiring application in the presence of non-targeted species (Couch and Nelson 1982). Triclopyr, like 2,4-D, is a selective (broadleaf vegetation) and systemic herbicide that breaks down in a relatively short period of time, and therefore is best applied in slower moving waters. The herbicide does not appear to be toxic to non-target organisms and the use of Triclopyr may serve to be a beneficial management strategy for allowing the native vegetation to reestablish following treatment (Getsinger et al. 1997).

Another herbicide used to control EWM is Floridone. Results indicate that fluridone is more selective at lower concentrations for EWM, but generally considered nonselective herbicide. As treatment concentrations increase, biomass levels of non-targeted species decrease at about the same rate as EWM. This herbicide is best used in situations where water is stagnant or slow moving. The half-life of this herbicide is about 33 days, which could be a concern, based on management goals and objectives (Netherland et al. 1997). Finally, Endothall is a contact herbicide that can be used in sensitive aquatic environments (Reinert et al. 1988) and in situations where levels of particulate or dissolved organic matter content are high (Madsen 2000). The downside of this herbicide is that it is not systemic and that it does not affect belowground parts of the plant. It may be good to use a strategy of endothol application, wait for the above-sediment biomass to breakdown, and follow up with rotovation.

A lower-cost alternative may be to use benthic barriers: bottom-coverings that smother and shade plants, killing them within a growing season (Madsen 2000). This method would be appropriate because it is recommended for small areas only (being too expensive for large infestations). Alternatively, it may be possible to use repeated winter drawdowns to eliminate the colony, as was unintentionally done in 1996. Such drawdowns, if feasible, would have to be repeated upon any future appearance of the plant in the same area. This would necessitate a careful monitoring program to ensure early detection of any newly established colony.

It is likely that the colony was introduced accidentally by a recreational boater using the nearby public access ramp (B. Alexander, pers. comm.). The other possible source is Lake Ashtabula, but the lake and upstream surveys in 1997 did not identify any other EWM (Alexander 1998). Authorities should consider closing or restricting use of the public access ramp until eradication has been completed. Whatever control methods are chosen, the entire Sheyenne River should be surveyed for EWM. If the species already has spread downstream undetected, the expense and effort of eradication at the Valley City site may be ineffective in preventing wider infestation.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Overall Likelihood of Interbasin Transfer

Only two PBOC species were assigned BRA status. This is because all others were either known or considered likely to be present in the Red River basin. Many species have not been reported in the Red River basin but were found to have sufficient means of overland or airborne dispersal, such that the proposed outlet would have little, if any, impact on their presence or invasiveness in the Red River basin. Other species not initially known to be in the Red River basin were subsequently confirmed as being there based on published scientific literature or from unpublished information provided by experts contacted for this study. Striped bass and Eurasian watermilfoil were carried forward to BRA stage. None of the other automatically listed PBOC species are known to exist in the Devils Lake basin; hence they were not classifeid as BRA.

Substantial data gaps were encountered in a number of taxonomic groups. As a result, it is impossible to state definitively that all species currently in Devils Lake have been accounted for. To the contrary, it is likely that Devils Lake does harbor species that have not been analyzed in this study. Accordingly, there may be additional PBOC species that are currently unknown at this time. It is more likely, however, that many species not documented in either the Devils Lake or the Red River basin are actually present in both. Further field investigations in both the Devils Lake and Red River basins would be necessary to render a more definitive analysis of this question. The taxonomic groups where substantial data gaps were found are as follows:

1. Vascular plants. No Devils Lake or DLB wetland/aquatic flora lists were found, with the exception of five species mentioned in various sources listed in Schmidt (1999). A partial list of vascular plants was developed by project team members during field visits to Devils Lake, but a systematic survey has not yet been done.

2. Algae. While recent algae studies of Devils Lake were combined with the results of historic studies, the cumulative list probably remains incomplete. This is because the investigations suffered from certain shortcomings: (a) sampling was conducted over very limited temporal and spatial scales, (b) sampling was restricted to only a subset of habitats, and (c) sampling was restricted to Devils Lake only, ignoring the other surface waters of the basin. Algae of the Sheyenne and Red Rivers have been studied recently, also generating long species lists, but these studies also were limited in temporal and habitat scope. Field study comparing similar habitats in both basins would almost certainly reveal more common species records, indicating algal flora that is more similar between the two basins.

3. Fishes. Fish species records from Devils Lake were complete and reliable, except that no recent records from other waters within the Devils Lake basin were found. Fish species records for the Red river basin were also fairly complete and reliable. Given the recent habitat changes in Devils Lake, more current data would probably reveal changes in the abundance and distribution of species within the lake. However, such changes would not in and of themselves result in the presence of fish species in the lake that had previously been absent.

4. Non-Parasitic Invertebrates and Protozoa. Few studies of invertebrates of Devils Lake have been conducted. The most complete and reliable survey was very old (Young 1924), yet provides more complete records for some groups (e.g. Protozoa, Rotifera, Nematoda) than

exist for the Sheyenne or Red Rivers. The few other data sources were very incomplete, based on samples that were very limited in spatial, temporal, and habitat scope, and including very few identifications to the species level. Many taxa were not identified to even genus or family level. Sheyenne River fauna have been even less studied, although a macroinvertebrate study is presently ongoing. The study currently being performed by Dr. Andre Delorme may not produce species-level results unless a specific commitment is made to obtain this level of detail. A Red River macroinvertebrate data set was found, but also suffers from lack of taxonomic resolution and incomplete spatial, temporal, and habitat coverage. In sum, the present state of information on free-living invertebrate species is very far from complete for both basins.

5. Parasites of fishes. Recent studies of metazoan parasites of fishes of Devils Lake and the Sheyenne River provided reliable parasite species information, though it was dated and incomplete. No data were found for any other Red River basin sites, and thoroughness of the Red River basin records was even more questionable, because some fish species were little studied and geographic coverage was incomplete. Many species found in Devils Lake were common, widespread, non-host-specific, and easily spread by avian definitive hosts. Yet they have not been recorded from Red River basin waters, due most likely to the lack of research rather than the absence of such species.

6. Pathogens of fishes. No records of fish diseases or pathogens in either the DLB or RRB were found though intensive literature search and expert consultation were undertaken. While no pathogen data may have been collected, the lack of anecdotal reports of diseased fish or fish kills suggests that fish pathogens have not caused significant problems to date. A fish pathogen screening study currently being undertaken by the St. Paul District of the USACE is expected to substantially improve understanding of fish pathogens in both basins.

7. Parasites and pathogens of other vertebrates. Records of avian botulism outbreaks on Devils Lake were the only records of other vertebrate diseases found. Other diseases have not been apparent in Devils Lake wildlife.

8. Minnesota Prohibited and Regulated Species. No records of Minnesota-listed exotic invasive species presence in the Devils Lake basin were found, but few surveys of appropriate taxa (e.g. crayfish, macrophytes) have been done recently. The lack of records could therefore represent true absence or lack of detection effort.

Aside from presence or absence of PBOC species, the potential for outlet-related habitat changes in the Sheyenne and Red Rivers are also of concern. Such changes may create colonization opportunities for species that have not been successful there in the past. Based on the foregoing analysis, such species largely appear confined to algae that are either halophilic or are adapted to life in eutrophic waters with higher nitrogen levels (and higher N:P ratios) than currently occur in the Sheyenne River basin. However, predictions of water chemistry changes in this study were somewhat speculative because adequate nutrient data is lacking. Further study of projected nutrient-level alterations would be necessary to determine whether downstream habitats would truly change in ways assumed in this report.

4.2 Alternative Scenarios

Due to the smaller quantity of Devils Lake water being discharged and adherence to a 450 mg/L sulfate standard, the 300 cfs Constrained Outlet alternative would generate lower downstream salinity levels than the 480 cfs unconstrained Outlet alternative. Under the 480 cfs Unconstrained Outlet alternative, salinity in the Sheyenne River would be likely to periodically exceed the 450 mg/L sulfate standard. The actual salinity level in the Sheyenne River would vary by outlet alternative, scenario and control point but would generally be low enough so as not to favor the invasion of halophilic algae species from the Devils Lake basin. In addition, the halophilic species remaining in Devils Lake appear to be confined to the eastern part of the basin where salinity levels are relatively high. Under either of the constructed outlet alternatives, these halophiles exist far from the proposed outlet intake and would be very unlikely to be transferred by pumping from West Bay. It is not possible to determine at what salinity levels the Sheyenne River would become a suitable habitat for halophilic species in Devils Lake, or at what levels resident species would be driven away or disadvantaged. Such fine distinctions cannot readily be drawn due to the paucity of data on the range of salinity levels tolerated by various species and the relative competitive advantages afforded by various levels on one species versus another.

Under the No Action (natural spill) alternative, the eventual discharge of Stump Lake water to the Sheyenne River would affect salinity levels much more significantly. Computer simulation results reported by the USACE in background information on the outlet project indicate that No Action (natural spill) flows into the Sheyenne River could exceed 2,500 cfs. Such volumes would overtop the river channel and result in significant erosion and bank scour. These high flows in and of themselves would not provide a suitable habitat for Devils Lake species. However, the resulting salinity changes in Lake Ashtabula could substantially affect communities there by disadvantaging resident species and providing favorable habitat for invasive halophiles from Devils Lake. Overflow water from Stump Lake could have median salinity over 3,700 mg/L, and maxima up to 6,800 mg/L. This would likely create high enough salinity levels in Lake Ashtabula to stress many resident species, and would probably facilitate the invasion of several species in to the lake. Such species would potentially include "marine" Cyanobacteria (e.g. *Nodularia spumigena*) and green algae (e.g. *Enteromorpha intestinalis* and *E. prolifera*), wigeongrass (*Ruppia maritima*), and several "marine" rotifers, among others.

Devils Lake discharges would vary substantially in duration among the various alternatives and scenarios. Regardless of alternative, however, once discharges cease the water quality of the Sheyenne and Red Rivers should return essentially to pre-discharge conditions. Once this occurs, the freshwater species already living in those basins will again have the competitive advantage over any halophiles that may have been temporarily advantaged.

4.3 Recommendations

4.3.1 Eradicate the Valley City Eurasian watermilfoil population

Regardless of which alternative is selected, the presence of a Eurasian watermilfoil population in the Sheyenne River presents a threat of downstream spread of this noxious weed species. A careful survey of the Sheyenne River and, ideally, the Red River as well, should be carried out as soon as possible to determine whether the existing population has spread. Equally important, the

Valley City population should be eradicated as soon as possible, with follow-up monitoring to ensure success. Methods are recommended in the Risk Management section of the risk assessment above.

4.3.2 Additional Field Studies

Many obstacles were encountered in the course of this project which prevented a strict adherence to the Statement of Work. Most of these obstacles were the result of inadequate data on the biota of the Devils Lake and Red River basins. Thus, if all the questions posed in the Statement of Work were to be answered in full, field study must be carried out on at least two topics:

A. Striped bass in Devils Lake

The level of risk of striped bass transfer to downstream waters hinges on whether striped bass are present and reproducing in Devils Lake. While no recent surveys have found striped bass, a focused search for spawning striped bass adults, larvae, and juveniles, during breeding season in the very few potential breeding habitats may answer the question. This would allow more appropriate decisions regarding pump intake screening measures, should an outlet be constructed.

B. Known exotic invasive species.

While no Minnesota-listed or other known exotic invasive species are known to occur in Devils Lake basin waters, that does not allow a definitive conclusion that none are present. The recent water level rise has created much new favorable habitat in Devils Lake for many species and has attracted increasing numbers of fisherman and recreational boaters. These anthropogenic factors are among the most important vectors of several harmful species in areas that they have invaded.

Aggressive, focused studies should be implemented to confirm that none of these known problem species have become established in Devils Lake. These species include zebra mussel (*Dreissena polymorpha*), spiny water flea (*Bythotrephes cederstroemi*), rusty crayfish (*Orconectes rusticus*), and perhaps others (e.g. Eurasian watermilfoil, mystery snail, zander). Any of these species could possibly find very favorable habitat in Devils Lake. The zebra mussel in particular could exploit the newly freshened habitats that have traditionally been too saline for mussels.

C. Varied habitats in both basins.

Almost all studies cited in this report were carried out in the main waters of the Devils Lake and Red River basin, yet many other surface water habitats occur in each basin. A multitude of wetlands and small lakes and tributaries exist in eastern North Dakota, encompassing a broad diversity of habitat conditions. Studying the biota of these systems would probably reveal a high level of biotic similarity between the Devils Lake and Red River Basins, with the greater level of variation occurring among habitat types within these basins.

4.3.3 Monitoring and Public Education

To minimize the risks of transfer of undesirable biota into waters downstream from the outlet, monitoring and outreach programs should be used in North Dakota as they have been used in other states. These should include monitoring water chemistry at the outlet, Lake Ashtabula, and at the Sheyenne River's mouth, at a minimum. Monitoring systems are already in place through the USGS, but it appears that nutrient levels are not as consistently measured as are salinity, metals, and contaminants.

Also, as noted above, a thorough search for EWM in the Sheyenne River should be conducted to determine whether the known population has spread.

Biotic monitoring programs should also be enacted to create an alert system that would be triggered if exotic species are found in Devils Lake or in the Sheyenne River. These programs should include public education regarding boat and trailer cleaning (to remove EWM fragments) and identification of exotic fish species (e.g. zander, grass carp), and surveillance of boats and trailers by government officers at public launch sites.

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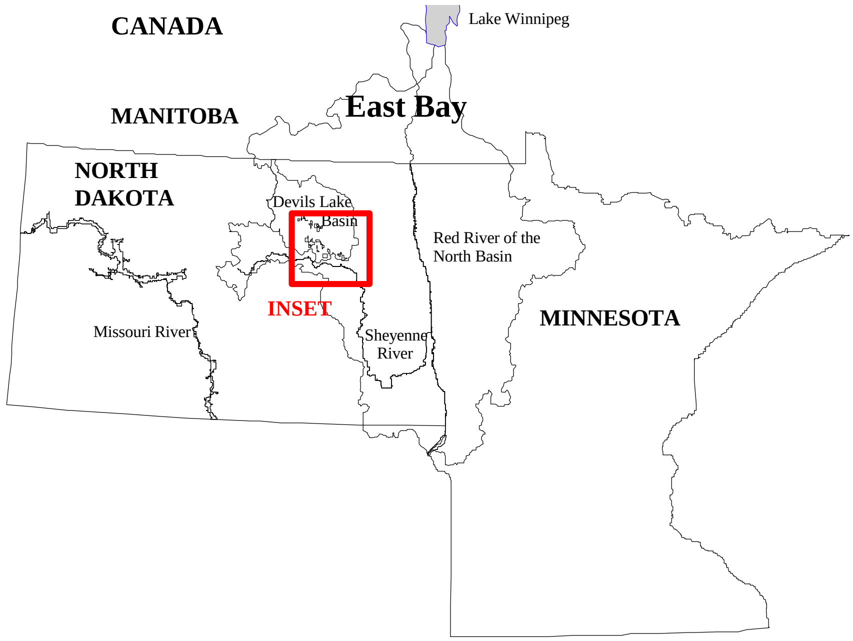
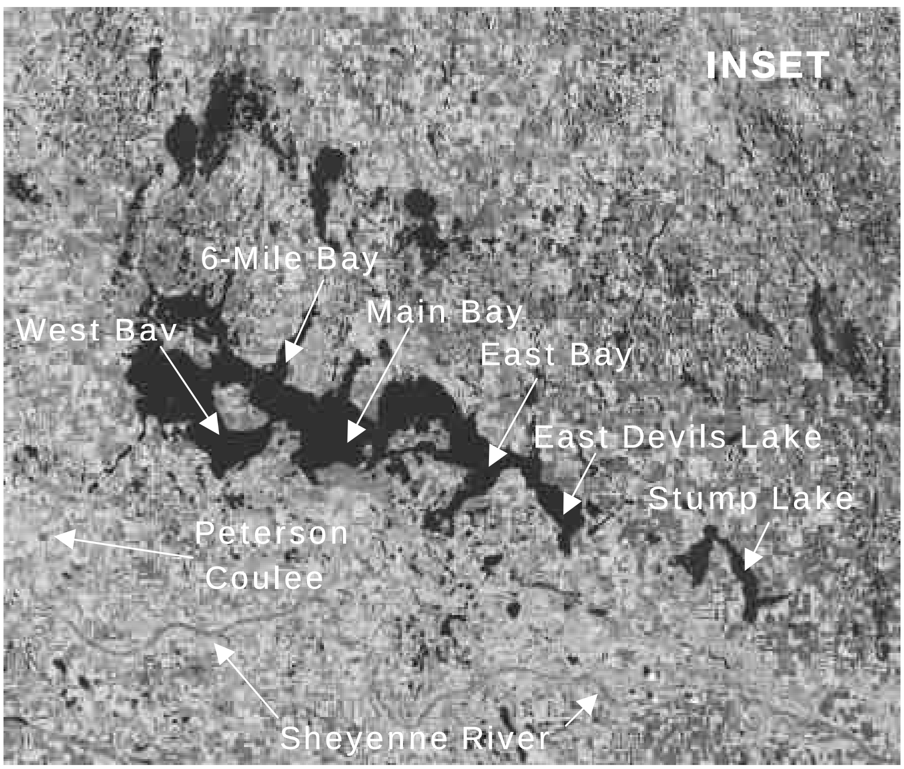
FIGURES



Location of Devils Lake basin



Project Location

Devils Lake Biota Transfer Study
Devils Lake, ND

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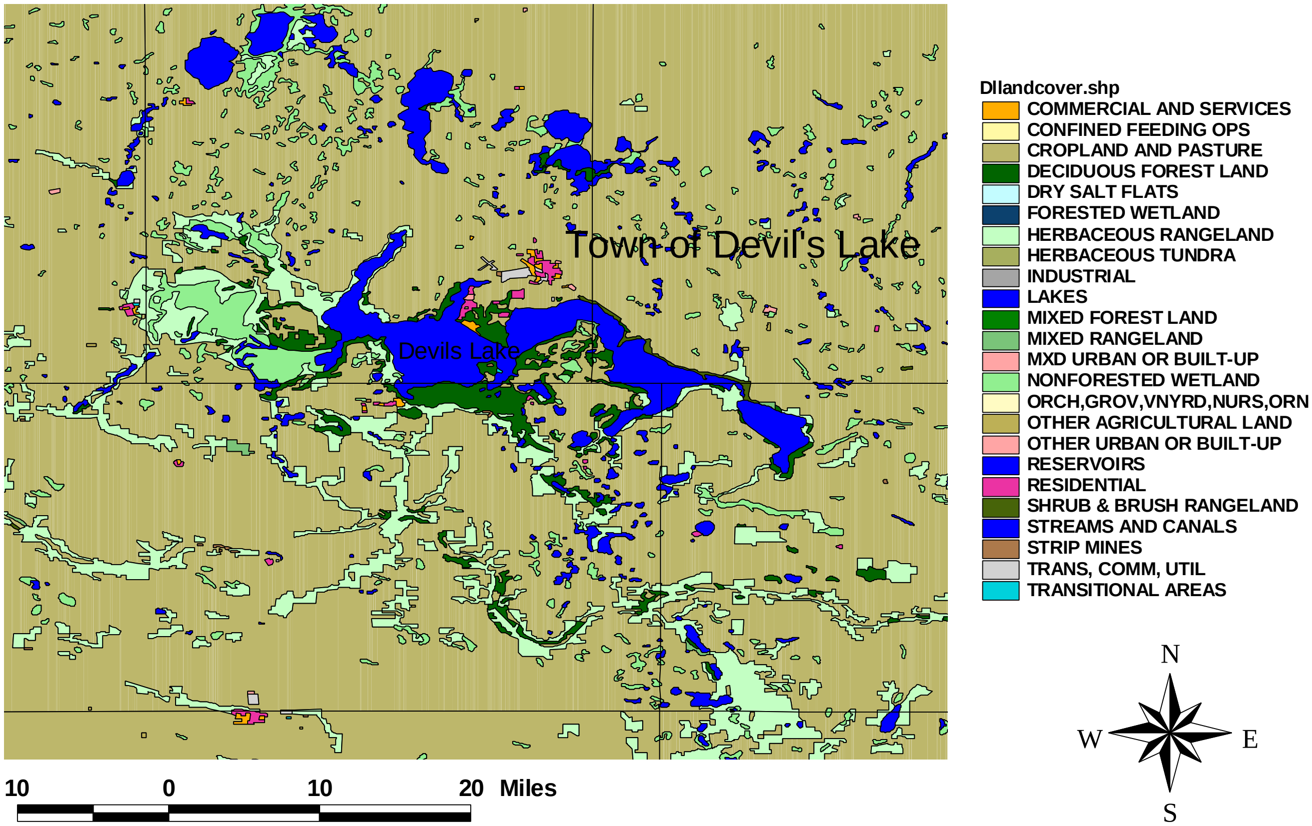
FIGURE 1

PETERSON ENVIRONMENTAL CONSULTING, INC.

PEC Project No. 2001-029

Devil's Lake North Dakota Land Cover Types



Map prepared from USEPA 1996 Arc View regional database. Land cover category names are those existing in the Arc View data tables.

Land Uses Surrounding Devils Lake

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Devils Lake Biota Transfer Study
Devils Lake, ND

FIGURE 2

PETERSON ENVIRONMENTAL CONSULTING, INC.

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3A. Bulrush-dominated shoreline community in Main Bay, Devils Lake.

3B. Cattail marsh shoreline in Devils Lake.

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Devils Lake Photos

Devils Lake Biota Transfer Study
Devils Lake, ND

FIGURE 3

PEC Project No. 2001-029

4A. Flooded snag forest in Devils Lake.

4B. Mud flat shore zone in Devils Lake. This "new" habitat will be colonized by pioneer plant species in subsequent years unless wave activity prevents it.

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Devils Lake Photos

Devils Lake Biota Transfer Study
Devils Lake, ND

FIGURE 4

PEC Project No. 2001-029

5A. **Devils Lake shoreline zone showing signs of eutrophic conditions. Green covering on surface is a dense growth of duckweed (*Lemna* sp.)**

5B. **Halophilic vegetation of mesosaline shoreline zones in Devils Lake.**

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Devils Lake Photos

Devils Lake Biota Transfer Study
Devils Lake, ND

FIGURE 5

PEC Project No. 2001-029

TABLES

Table 1. Taxa automatically listed as Potential Biota Of Concern (PBOC).

Vascular Plants
[1]*Butomus umbellatus* Linnaeus - flowering rush
[2]*Cabomba caroliniana* Gray - Carolina fanwort or fanwort
[1]*Crassula helmsii* (Kirk) Cockayne - Australian stonecrop
[1]*Hydrocharis morsus-ranae* Linnaeus - European frog-bit
[1]*Hydrilla verticillata* (Linnaeus) Royle -hydrilla
[1]*Hygrophila polysperma* (Roxburgh) Anders - Indian swampweed
[1]*Lagarosiphon major* (Ridley) Moss ex Wagner - African oxygen weed
[1]*Lythrum salicaria* Linnaeus, *Lythrum virgatum* Linnaeus, or any variety, hybrid, or cultivar thereof - purple loosestrife
[2]*Myriophyllum aquaticum* (da Conceicao Vellozo) Verdcourt - parrot's feather
[1]*Myriophyllum spicatum* Linnaeus - Eurasian water milfoil
[2]*Nymphaea* spp. Linnaeus, or any variety, hybrid, or cultivar thereof except *N. odorata odorata* Aiton, *N. leibergeii* Morong, and N. *odorata tuberosa* (Paine) Wiersema & Hellquist. - non-native waterlilies
[1]*Potamogeton crispus* Linnaeus - curly-leaf pondweed
[1]*Salvinia molesta* Mitchell - aquarium watermoss or giant salvinia
[1]*Stratiotes aloides* Linnaeus - water aloe or water soldiers
[1]*Trapa natans* Linnaeus - water chestnut

Invertebrates
[2]*Bythotrephes cederstroemi* Schoedler - spiny water flea
[2]*Cipangopaludina* spp. Hannibal (e.g. *C. chinensis*, *C. chinensis malleata*, *C. japonica*) - Chinese mystery snail, Japanese mystery snail, Japanese trap door snail
[1]*Dreissena polymorpha* Pallas - zebra mussel
[2]*Orconectes rusticus* Girard - rusty crayfish

Fishes
[2]*Alosa pseudoharengus* Wilson - alewife
[2]*Carassius auratus* Linnaeus - goldfish
[1]*Ctenopharyngodon idella* Valenciennes - grass carp
[2]*Cyprinus carpio* Linnaeus - common carp, koi
[1]*Gymnocephalus cernuus* Linnaeus - ruffe
[1]*Hypophthalmichthys molitrix* Valenciennes - silver carp
[1]*Hypophthalmichthys nobilis* Richardson - bighead carp
[1]*Morone americana* Gmelin - white perch
[3]*Morone saxatilis* Walbaum - striped bass
[1]*Mylopharyngodon piceus* Richardson - black carp
[1]*Neogobius melanostomus* Pallas - round goby
[2]*Osmerus mordax* Mitchell - rainbow smelt
[1]*Petromyzon marinus* Linnaeus - sea lamprey
[1]*Scardinius erythrophthalmus* Linnaeus - rudd
[1]*Stizostedion lucioperca* Linnaeus - zander
[2]*Tilapia* spp., *Oreochromis* spp., *Sarotheradon melanotheron* Rüppell - tilapia

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Table 1. Continued.

<u>Pathogens & Parasites of Fish</u>
[3]*Heterosporis* Schubert (species unknown), the protozoan "Yellow Perch Parasite"
[3]Infectious Pancreatic Necrosis Virus (IPNV)
[3]Infectious Hemotopoietic Necrosis Virus (IHNV)
[3]Largemouth Bass Virus (LMBV)
[3]*Myxobolus cerebralis* Hofer, the protozoan pathogen of whirling disease, and its intermediate invertebrate host *Tubifex tubifex* Müller, an annelid worm
[3]Parasites/pathogens of striped bass
[3]*Renibacterium salmoninarum* Sanders and Fryer, Bacterial Kidney Disease (BKD)

[1]Minnesota Prohibited Species
[2]Minnesota Regulated Species
[3]Species named in Statement of Work

Table 2. Collection locations of algae classified as Candidate PBOC, with citations to sources listed below table. (Location codes: DL=Devils Lake, US=Upper Sheyenne River, LA=Lake Ashtabula, LS=Lower Sheyenne River, ML=Matejcek Lake (Red River drainage), RR=Red River of the North, LW=Lake Winnipeg, CL=Cottonwood Lakes area (Missouri River drainage).

Taxon (including synonyms where applicable)	**DL**	**US**	**LA**	**LS**	**ML**	**RR**	**LW**	**CL**
Chlorophyta - green algae								
Actinastrum hantzschii	2,11,16					5		
Aestrococcus sp.	3	3	3	3				
Ankistrodesmus falcatus falcatus	11							
Ankistrodesmus falcutus	15,13,16,2,14		14			5		8
Ankyra judayi	11							
Botryococcus braunii	15,16							
Botryococcus sp.	10			4				
Characium hookeri	15,13,16					5		
Characium sp.	7					5		
Characium sp. "1"	3	3						
Characium sp. "2"	3	3						
Characium sp. "3"	3							
Chlamydomonas globosa	3	3	14	3	14			
Chlamydomonas sp.	15,13,16,6,7,11	4				5		8
Chlorella vulgaris	15,16,6,11							8
Chlorella sp.	2,11,13							8
Chlorococcum sp.	13,11							8
Chlorogonium sp.	16,6,11							8
Choricystis minor	16,6							
Cladophora crispata	13							
Cladophora fracta	15,13							
Cladophora glomerata var. *keutzingiana*	15							
Cladophora keutzingiana	16							
Cladophora sp.	1,2,16							
Clathrocystis aeruginosa	16							

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Closteriopsis longissima	11					5		
Closterium acutum	10							
Closterium dianae	16					5		
Closterium dianae arcuatum	16							
Closterium lunata	3	3						
Closterium parvulum var. *angustissima*	10							
Closterium pronum	10							
Closterium subcostatum	16							
Closterium sp.	15,13,16,2					5		8
Coccomonas sp.	11							
Coccomyxa sp.	11							
Coelastrum microporum	15,13,10,16,2,11	4				5		
Coelastrum sphaericum	11					5		
Coelastrum sp.	9							8
Coenochloris pyrenoidosa	11							
Coenochloris sp.	11							
Cosmarium formulosum	16					5		
Cosmarium scopularum	16							
Cosmarium sub-costatum	16							
Crucigenia apiculata	11					5		
Crucigenia quadrata	6,11					5		
Crucigenia tetrapedia	11					5		
Dictyosphaerium ehrenbergianum	16,11	4		4		5		8
Dictyosphaerium pulchellum	15,10,13,11	4				5		
Dictyosphaerium sp.	2,11					5		8
Dunaliella sp.	6,11							8
Dunaliella viridis	11							
Dysmorphococcus sp.	11							
Elakatothrix gelatinosa	11							

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Elakatothrix viridis	11							
Enteromorpha intestinalis	13,16,2							
Enteromorpha prolifera	15,16,1							
Enteromorpha sp.	16							
Eudorina elegans	16,2,14				14	5		
Eudorina sp.	3		S			5		
Gloecoccus sp.	11							
Gloeocystis gigas	11					5		
Gloeocystis major	13,2,11							
Gloeocystis sp.	15,2					5		
Gloeocystis sp. "1"	3	3	3					8
Gloeocystis sp. "2"	3							
Gongrosira sp.	3							
Gonium sp.	3	3	3					
Kentrosphaeria sp.	11							
Keratococcus sp.	11							
Kirchneriella contorta	11							
Kirchneriella elongata	11							
Kirchneriella lunaris	6,11					5		
Kirchneriella subsolitaria	11							
Kirchneriella sp.	9,10	4		4				
Mesotaenium sp.	11					5		8
Micractinium pulsillum	11					5		
Monoraphidium contortum	3,10,11	4	3	4				
Monoraphidium minutum	10,11	4	4	4				
Monoraphidium mirabile	11							
Monoraphidium pusillum	10	4	4	4				
Monoraphidium tortile	10	4		4				
Monoraphidium sp. "1"	3			3				

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Monoraphidium sp. "2"	3	3		3				
Monoraphidium sp. "3"	3							
Mougeotia sp.	15,10,13,16,2,7,11					5		8
Nannochloris sp.	11							
Nephrocytium agardhianum	11	4						
Nephrocytium limnetica	11					5		
Nephrocytium lunatus	11	4						
Nephrocytium naegelii	16							
Nephrocytium sp.	11							
Oedogonium sp.	16					5		
Oocystis borgei	11		14			5		
Oocystis crassa	16,11							
Oocystis eremosphaeria	11,14		14			5		
Oocystis gloecystiformis	11							
Oocystis lacustris	16,11					5		
Oocystis naeglii	16							
Oocystis novae-semliae v. *maxima*	15,13							
Oocystis parva	11		14					
Oocystis pusilla	16,11					5		
Oocystis pyriformis	11							
Oocystis solitaria	16					5		
Oocystis submarina	11							
Oocystis sp.	6,9,11,14					5		8
Pandorina morum	16		14			5		
Pandorina sp.	16							
Pascherina tetras	14							
Pediastrum angulosum	16							
Pediastrum boryanum	15,13,10,16,11	4				5		8
Pediastrum duplex	10,11	4	14			5		

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Pediastrum duplex var. *Clathratum*	15,13,10,2,14	4				5		
Pediastrum sp.	10,9							
Protoderma viride	16							
Pseudosphaerocystis lacustris	11							
Pseudoulvella sp.	3							
Pyramimonas sp.	11	3				5		8
Raphidonema sp. "1"	10	4	4	4				
Raphidonema sp. "2"	10	4		4				
Rhizoclonium hieroglyphicum	16					5		
Rhizoclonium sp.	9							
Scenedesmus abundans	11					5		8
Scenedesmus acuminatus	11					5		
Scenedesmus bicaudatus	11					5		
Scenedesmus bijuga	2				14	5		8
Scenedesmus bijugatus	16							
Scenedesmus dimorphus	11	4	14	4		5		8
Scenedesmus ecornis	6,11					5		
Scenedesmus granulatus	11							
Scenedesmus intermedius	14							
Scenedesmus linearis	11							
Scenedesmus opoliensis	15,13,11							
Scenedesmus quadricauda	2,11	4	14			5		8
Scenedesmus quadricauda typicus	16							
Scenedesmus subspicatus	11							
Scenedesmus sp.	3,7,9,11	3				5		8
Scherffelia sp.	7					5		
Schroederia judayi	10							8
Schroederia setigera	6,11,14		14		14	5		8
Schroederia sp.	13,2,7,9					5		

Table 2. Continued.

Taxon (including synonyms where applicable)	**DL**	**US**	**LA**	**LS**	**ML**	**RR**	**LW**	**CL**
Selanastrum sp.	13,2,9					5		8
Sphaerocystis schroeteri	15,13,11,14				14	5		
Sphaerocystis sp.	7,9							
Spirogyra sp.	15,13,2					5		8
Staurastrum sp.	16,2,9					5		8
Stephanoptera gracilis	11							8
Stichococcus sp.	15,13,2,9							
Stigeoclonium attenuatum	13							
Stigeoclonium nanum	16							
Stigeoclonium sp. "1"	3	3	3					
Stigeoclonium sp. "2"	3	3						
Tetraedron caudatum	11					5		8
Tetraedron minimum	11					5		
Tetrastrum heterocanthum	11					5		
Tetrastrum staurogeniaeforme	11		14			5		
Ulothrix aequalis	15,13							
Ulothrix zonata	16					5		
Ulothrix sp.	2					5		8
Vaucheria sp.	16							
Zoochorella conductrix	16							
Chrysophyta; Order Bacillariophyceae - diatoms								
Achnanthidium clevei, Achnanthes cl.	11,16							
Achnanthidium microcephalum, Achnanthes microcephala	16							
Amphora coffeiformis	9,11					5		
Amphora ovalis	15,13,16,3,9	3	3	3		5		8
Amphora pediculus, A. ovalis pediculus	11	3		3		5		
Amphora proteus	16							
Amphora veneta	11					5		8
Amphora sp.	2,7,9							

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Anomoeoneis serians	9							
Anomoeoneis sphaerophora	169					5		
Asterionella formosa	10	4	14			5		
Aulacoseira granulata	10,11	4	14	4		5		
Aulacoseira granulata var. *augustissima*	10,11			4				
Aulacoseira italica	10					5		
Cymbella elginsis, C. turgida, Encyonema turgidum	15,13							
Caloneis amphisbaena	11					5		
Caloneis bacillaris var. *thermalis*	11							
Campylodiscus clypeus	16							
Campylodiscus sp.	9					5		
Carteria sp.	11	3				5		8
Catacombus gaillonii	10							
Cavinicula lacustris, Navicula lac.	16							
Chaetoceros elmorei	15,13,16,2,11,14					5		
Chaetoceros muelleri	6							
Chaetoceros sp.	10,11							
Cocconeis pediculus	16					5		
Cocconeis placentula	16,9					5		8
Cocconeis placentula var. *euglypta*	3	3	3	3		5		
Cocconeis sp.	13,14		14					
Craticula acommoda	3,11					5		8
Craticula ambigua	16,3							
Craticula cuspidata, Navicula fulva	16							
Ctenophora pulchella, Synedra pul.	16,11							8
Cyclostephanos dubius, Stephanodiscus dub.	11							
Cyclostephanos sp.	3					5		
Cyclotella bodanica	15,10,13,2					5		
Cyclotella kutzingiana	11					5		

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Cyclotella meneghiniana	16,10,6,9,11		14		14	5		8
Cyclotella pediculus	11							
Cyclotella radiosa, C. comta	16							
Cyclotella stelligera	10,6,11			4		5		
Cyclotella stelligera var. *glomerata, C. glom.*	10			4		5		
Cyclotella striata	16					5		
Cyclotella sp.	2,9,11							
Cymatopleura sp.	2				14	5		
Cymbella aequalis	16							
Cymbella affinis, C. parva	16							
Cymbella cistula	16					5		8
Cymbella mexicana	3	3	3			5		
Cymbella proxima	3	3	3					
Cymbella pusilla	16					5		
Cymbella sp.	2,9		14			5		
Denticula elegans	16					5		
Denticula sp.	9					5		
Diatoma tenue	16,3,6,11	3	3	3		5		
Encyonema minutum, Cymbella minuta	3			3				8
Encyonema prostratum, Encyonema prostrata	3		3					
Entomoneis alata	16,11					5		
Entomoneis paludosa	6,11					5		8
Entomoneis sp.	2,14							
Epithemia adnata	16,11					5		
Epithemia argus	16,11					5		
Epithemia ocellata, Cystopleura oc.	16							
Epithemia sorex	16,3	3	3			5		
Epithemia turgida	9					5		
Epithemia sp.	15,13,9					5		

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Eunotia curvata, E. lunaris	16					5		
Eunotia sp.	9					5		
Fallacia pygmaea, Navicula pyg.	16							8
Fragilaria capucina	11					5		8
Fragilaria capucina mesolepta	3,11	3	3	3		5		8
Fragilaria crotonensis	15,13,2		14			5		8
Fragilaria vaucheriae	3,11	3	3	3		5		
Fragilaria sp.	11		14					
Gomphoneis sp.	3	3	3			5		
Gomphonema acuminatum	9					5		
Gomphonema angustatum	3	3	3	3		5		8
Gomphonema brebissonii	3							
Gomphonema gracile	16,3	3				5		8
Gomphonema intricatum	3	3				5		
Gomphonema montanum	16							
Gomphonema olivaceum	3	3	3	3		5		
Gomphonema olivaceum var. "1"	3	3	3	3				
Gomphonema parvulum	16,3	3	3	3		5		8
Gomphonema subclavatum	9					5		
Gomphonema subclavatum var. *mexicanum*	3	3	3					
Gomphonema truncatum	3					5		
Gomphonema sp.	15,13,2,11					5		8
Gyrosigma acuminatum	3,16,11			4				8
Gyrosigma attenuatum	3	3						
Gyrosigma sp.	15,13,2,7,9				14	5		
Hannaea arcus	3					5		
Hantzschia amphioxys	16,11					5		8
Lemnicola hungarica, Achnanthes hung.	16							
Mastogloia elliptica	16					5		

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Mastogloia smithii	16					5		
Melosira sp.	9					5		8
Navicula agnewii	11							
Navicula anglica	16					5		
Navicula capitata	3,11	3	3	3		5		8
Navicula capitata var. *capitata*	11							
Navicula capitata var. *hungarica*	16,11					5		
Navicula cincta	16,11					5		8
Navicula crucicula	16							
Navicula cryptenella	3			3				
Navicula cryptocephala	16,11					5		8
Navicula cryptocephala var. *veneta*	11					5		8
Navicula decussis	9					5		
Navicula fonticula	9							
Navicula gastrum	16							
Navicula heufleri	11					5		8
Navicula lanceolata	16					5		8
Navicula miniscula	11							8
Navicula minnewaukonensis	16,11							
Navicula navicularis	9							
Navicula oblonga	16,9					5		
Navicula pelliculosa	11					5		
Navicula reinhardtii	3,9	3	3	3		5		
Navicula scandinavica	16							
Navicula subminiscula	11							
Navicula tripunctata	3,11					5		8
Navicula tryblionella	9							
Navicula vaucheriae	11							
Navicula ventosa	11							

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Navicula sp.	15,13,2,6,9,11,14	3	14		14			8
Neidium iridis, Navicula ir.	16							
Neidium sp.	7					5		
Nitzschia adapta	11							
Nitzschia angustata, Homoeocladiea ang.	16							
Nitzschia attenuata	3							
Nitzschia commutatoides, Homoeocladia commutata	16							
Nitzschia dissipata	3,11	3	3	3		5		
Nitzschia fonticola	3,6		3			5		8
Nitzschia frustulum	3,10,11	3,4		4		5		8
Nitzschia gandersheimiensis	11							
Nitzschia gracilis	11					5		
Nitzschia halophila	11							
Nitzschia hantzschiana	11					5		8
Nitzschia inconspicua	10	4	4	4				8
Nitzschia lanceolata, Homoeocladia lan.	16							
Nitzschia linearis	11					5		8
Nitzschia lorenziana	11					5		
Nitzschia palea	16,11					5		8
Nitzschia paleacea, N. kuetzingiana	11					5		
Nitzschia pura	10					5		
Nitzschia reversa	10,7,11,14					5		8
Nitzschia sigmoidea	11					5		
Nitzschia sp.	3,13,2,6,9,14		14		14	5		8
Nitzschia sp. "2"	3			3				
Nitzschia subacicularis	10					5		
Nitzschia umbonata	11					5		
Nitzschia vermicularis	16,3					5		
Nizschia stagnorum, Homoeocladia stag.	16							

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Pinnularia brebissoni, Navicula breb.	16							
Pinnularia major, Navicula maj.	16							
Pinnularia microstauron	3					5		
Pinnularia stauroptera, Navicula parva	16							
Pinnularia subcapitata, Navicula subcapitata	16							
Pinnularia sp.	9		14			5		8
Planothidium delicatulum, Achnanthes delicatula	16							
Planothidium hauckianum, Achnanthes hauckiana	11					5		
Planothidium lanceolatum, Planothidium lanceolata	16							
Rhoicosphenia curvata	15,13,16,3,9,14	3	3	3				8
Rhoicosphenia sp.	2					5		
Rhopalodia gibba	16,3	3		3		5		8
Rhopalodia gibba var. *ventricosa, Cystopleura ventricosa*	16							
Rhopalodia sp.	9					5		
Scoliopleura peisonis	16							
Staurosira construens, Fragilaria con.	16							
Stephanodiscus actrea	9							
Stephanodiscus agassizensis	6					5	27	
Stephanodiscus alpinus	11					5		
Stephanodiscus astraea	14					5		
Stephanodiscus corconensis	16							
Stephanodiscus hantzschii	6,11					5		
Stephanodiscus minutulus	6					5		
Stephanodiscus niagarae	10,6,11		14		14	5	27	
Stephanodiscus rotula	10							
Stephanodiscus sp.	9,11		14			5		
Surirella angustata	3,9		3	3		5		
Surirella brebissonii	16,3,9,11,14	3						
Surirella fastuosa	9							

Table 2. Continued.

Taxon (including synonyms where applicable)	**DL**	**US**	**LA**	**LS**	**ML**	**RR**	**LW**	**CL**
Surirella ovalis	11					5		
Surirella peisonis	15,13,6							
Surirella robusta	11							
Surirella striatula	16,9							
Surirella sp.	2,9,14		14			5		
Synedra acus	16,3,10,11	3	3	3		5		
Synedra amphicephala	16							
Synedra delicatissima	3	3				5		
Synedra montana	3							
Synedra ulna	16, 3	3	14	3		5		8
Synedra sp.	2,7,9	4		4		5		8
Tabularia fasciculata, Synedra fasc.	3,10,11	3		3		5		8
Tabularia tabulata, Synedra tab.	16,11							
Thalassiosira bramaputrae, Coscinodiscus lacustris	9							
Tryblionella appiculata	3	3		3				
Tryblionella hungarica, Homoeocladia hung.	16							
Tryblionella hungarica, Nitzschia hung.	11							8
Tryblionella tryblionella, Nitzschia tryb.	16,11							8
Chrysophyta; Order Chrysophyceae - yellow-brown algae								
Bicosoeca sp.	10							
Chromulina nebulosa	10	4	4	4				
Chromulina ovalis	10			4				
Chromulina pseudonebulosa	10	4		4				
Chrysamoeba radians	10							
Chrysocapsa vernalis	10							
Chrysococcus cordiformis	10	4	4	4				
Chrysococcus elegans	10			4				
Chrysococcus ornatus	10							
Chrysococcus punctiformis	10	4	4	4				

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Chrysococcus rufescens	10	4		4				
Kephyrion cordatum	10			4				
Kephyrion globosum	10							
Kephyrion impletum	10							
Kephyrion limneticum	10			4				
Kephyrion littorale	10	4	4	4				
Kephyrion planktonicum	10							
Kephyrion sitta	10	4		4				
Kephyrion skujae	10							
Mallomonas aerolata	10			4				
Mallomonas sp.	10	4						8
Ochromonas fragilis	10							
Ochromonas minuta	10	4		4				
Ochromonas sp.	11	4						8
Synura sp.	9							8
Chrysophyta; Order Xanthophyceae - yellow-green algae								
Characiopsis cylindrica	3							
Characiopsis subulata	3							
Peroniella planktonica	3	3		3				
Odontidium elongatum	16							
Sorastrum spinulosum	15							
Spermatozoopsis sp.	14							8
Sphinctocystis librilis	16							
Cryptophyta								
Chroomonas acuta	10,14	4	14	4				
Chroomonas nordstedtii	10	4	4	4				8
Chroomonas sp.	6,11		14					8
Cryptochrysis commutata	10							
Cryptomonas curvata	10							

Table 2. Continued.

Taxon (including synonyms where applicable)	**DL**	**US**	**LA**	**LS**	**ML**	**RR**	**LW**	**CL**
Cryptomonas erosa	10	4	14	4	14			8
Cryptomonas gracilis	10	4		4				
Cryptomonas marsonii	10,11	4	4	4				8
Cryptomonas ovata	10,11	4		4				8
Cryptomonas reflexa	10	4	14	4				
Cryptomonas sp.	9,14				14			8
Rhodomonas minuta	10	4	4	4				8
Rhodomonas minuta var. *nannoplanktica*	10	4	4	4				
Rhodomonas pusilla	10	4	4	4				
Rhodomonas rubra	10							
Cyanobacteria - blue-green algae								
Anabaena flos aquae	3,16,6,11	3						
Anabaena spiroides	15,10,13,16,2							
Anabaena sp.	9,14	4	14		14			8
Anabaenopsis elenkinii	2,11							
Anacystis nidulans	11							
Anacystis saxicola	11							
Anacystis sp.	11							
Ankistrodesmus sp.	7,9				14			8
Aphanizomenon flos-aquae	10,13,2,6,11,14		14	4	14			
Aphanizomenon sp.	15,7,9							8
Aphanocapsa delicatissima	11							8
Aphanocapsa elachista	11							8
Aphanocapsa elachista var. *coferta*	11							
Aphanocapsa sp.	6,7							8
Aphanothece castagnei	16							8
Aphanothece sp.	6					5		8
Arthrospira jenneri	16							
Calothrix braunii	16					5		

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Calothrix fusca	16					5		
Calothrix parietina	16					5		
Chamaesiphon sp.	3	3				5		8
Chroococcus dispersus	16,11					5		8
Chroococcus limneticus	3,16	3	3	3		5		
Chroococcus minimus	11					5		
Chroococcus minutus	16							
Chroococcus turgidus	16							
Chroococcus sp.	6,7,11	4	4,14			5		8
Coelosphaerium collinsii	11							8
Coelosphaerium dubium	11							8
Coelosphaerium kuetzingianum	15,13,16,2,11					5		
Coelosphaerium naegelianum	11					5		
Coelosphaerium sp.	3					5		8
Dactylococcopsis acicularis	11							8
Dactylococcopsis fascicularis	6,11							8
Dactylococcopsis irregularis	14							8
Dactylococcopsis rhaphidioides	11					5		8
Dactylococcopsis sp.	11		14			5		8
Gloeocapsa aeruginosa	10	4	4	4				
Gloeocapsa lacustris var. *compacta*	10							
Gloeocapsa sp.	7,11							8
Gloetrichia natans	16							
Gomphosphaeria aponina	16,10,11					5		
Gomphosphaeria aponina cordiformis	16							
Gomphosphaeria lacustris	15,13					5		
Gomphospheria sp.	2,9,14,3					5		
Lyngbya birgei	11		S					8
Lyngbya contorta	16							

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Lyngbya limnetica	11					5		8
Lyngbya sp.	2,9		14					
Marssoniella elegans	11							8
Marssoniella sp.	11							
Merismopedia convoluta	16							
Merismopedia elegans	16					5		
Merismopedia glauca	16					5		
Merismopedia tenuissima	15,16,3,10,2,11	3,4				5		8
Merismopedia sp.	6,7,9					5		
Microcystis aeruginosa	15,10,13,2,6,11,14		14			5		
Microcystis incerta	16,10,14		4,14			5		
Microcystis sp.	9,11							8
Microspora loefgrenii	16							
Microspora sp.	11					5		8
Myxosarcina spectabilis	3	3	3					
Nodularia spumigena	15,13,16,6,11							
Nodularia sp.	7					5		8
Oscillatoria acutissima	10			4				
Oscillatoria amphibia	16							
Oscillatoria angustissima	10,11	4	4	4				8
Oscillatoria brevis	16							
Oscillatoria chalybea	16							8
Oscillatoria chlorina	16							8
Oscillatoria geminata	16							
Oscillatoria hamelii	11							
Oscillatoria janthiphora	16							
Oscillatoria lacustris	3	3	3					
Oscillatoria limnetica	11					5		8
Oscillatoria limosa	10,16					5		8

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Oscillatoria minima	3			3				
Oscillatoria nigra	3							
Oscillatoria prolifica	11					5		
Oscillatoria splendida	11					5		8
Oscillatoria subtilissima	16,11							
Oscillatoria tenuis	16,11					5		
Oscillatoria tenuis var. *tergestina*	11							
Oscillatoria sp.	15,13,16,2,6,7,11		14		14			8
Phormidium mucicola	11,14							
Phormidium sp.	3,11							8
Planktolyngbya subtilus	6							
Plectonema tenue	16							
Pseudabaena mucicola	6							
Pseudabaena sp.	11							8
Rhabdoderma irregulare	11							8
Rhabdoderma sigmoidea	16,6,11							8
Rhabdoderma sigmoidea f. *minor*	11							8
Rhabdogloea ellipsoidea	11							
Schizothrix sp.	3		3			5		8
Spirulina major	15,13,16							8
Spirulina norstedtii	16							
Spirulina subtilissima	16							
Spirulina tenerrima	16							8
Spirulina sp.	3,2,11					5		8
Synechococcus sp.	7,11							8
Tetrapedia gothica	16							
Tetrapedia sp.	16							
Tolypothrix lanata	16							

Table 2. Continued.

Taxon (including synonyms where applicable)	DL	US	LA	LS	ML	RR	LW	CL
Euglenophyta - euglenoids								
Euglena elongata	15,13,2							
Euglena limnephila var. *minor*	10	4						
Euglena polymorpha	3,11							
Euglena proxima	11							
Euglena sp.	6,7,11,14		14		14			8
Phacus sp.	14				14	5		8
Trachelomonas hispida	3	3,4		3		5		
Trachelomonas hispida var. *papillata*	3	4		3				
Trachelomonas horrida	11							
Trachelomonas pulchella	3	3		4				
Trachelomonas varians	10	4						
Trachelomonas volvocina	14		14			5		
Trachelomonas sp.	9,11		14		14	5		8
Pyrrhophyta, Class Dinophyceae - dinoflagellates								
Ceratium hirundinella	10		14			5		

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Table 2. Continued.

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Table 3. Candidate PBOC vascular plant species and locations where found in Devils Lake and Red River Basins.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Agrostis hyemalis (Walt.) B.S.P.	**1**		**1**	**1**	**1**	2	2
Alisma gramineum Lej.		**1**	**1**		**1**	2	1
Alisma plantago-aquatica		**1**	**1**	**1**	**1**	2	2
Alisma triviale		**1**				1	0
Alnus incana ssp. rugosa (Du Roi) Clausen	**1**		**1**	**1**	**1**	2	2
Alopecurus aequalis Sobol.			**1**		**1**	1	1
Althaea officinalis L.				**1**		0	1
Amelanchier alnifolia	**1**	**1**	**1**	**1**		3	1
Amorpha fruticosa L.				**1**	**1**	0	2
Anemone canadensis L.				**1**		0	1
Arisaema triphyllum (L.) Schott				**1**		0	1
Asclepias incarnata L.		**1**	**1**	**1**	**1**	2	2
Aster lateriflorus (L.) Britt.					**1**	0	1
Aster novae-angliae L.		**1**	**1**	**1**	**1**	2	2
Aster puniceus L.			**1**	**1**	**1**	1	2
Atriplex subspicata	**1**	**1**				2	0
Beckmannia syzigachne (Steud.) Fern.		**1**	**1**	**1**	**1**	2	2
Berula erecta (Huds.) Coville		**1**			**1**	1	1
Betula occidentalis Hook.				**1**		0	1
Bidens cernua L.			**1**		**1**	1	1
Bidens comosa (triparita)			**1**	**1**	**1**	1	2
Bidens connata Muhl. ex Willd.					**1**	0	1
Bidens frondosa L.	**1**	**1**	**1**	**1**	**1**	3	2
Bidens vulgata		**1**	**1**		**1**	2	1
Boehmeria cylindrica (L.) Sw.				**1**		0	1
Boltonia asteroides (L.) L'Hér.		**1**			**1**	1	1
Bromus latiglumis (Shear) A.S. Hitchc.		**1**			**1**	1	1
Calamagrostis canadensis (Michx.) Beauv.		**1**	**1**	**1**	**1**	2	2
Calamagrostis stricta ssp. stricta var. stricta (Timm) Koel.		**1**	**1**			2	0
Calla palustris L.				**1**		0	1
Callitriche hermaphroditica L.		**1**			**1**	1	1
Callitriche verna L. (palustris)		**1**			**1**	1	1
Caltha palustris L.		**1**	**1**	**1**	**1**	2	2

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Campanula aparinoides Pursh				**1**	**1**	0	2
Cardamine pensylvanica Muhl. ex Willd.				**1**		0	1
Carex aquatilis Wahlenb.		**1**		**1**	**1**	1	2
Carex assiniboinensis					**1**	0	1
Carex atherodes Spreng.			**1**		**1**	1	1
Carex athrostachya Olney		**1**				1	0
Carex aurea Nutt.		**1**	**1**		**1**	2	1
Carex bebbii Olney ex Fern.		**1**			**1**	1	1
Carex bicknellii Britt.			**1**		**1**	1	1
Carex brevior		**1**	**1**		**1**	2	1
Carex buxbaumii Wahlenb.		**1**			**1**	1	1
Carex crawei Dewey					**1**	0	1
Carex cristatella Britt.		**1**	**1**		**1**	2	1
Carex disperma Dewey					**1**	0	1
Carex eburnea					**1**	0	1
Carex eleocharis		**1**	**1**		**1**	2	1
Carex emoryi Dewey					**1**	0	1
Carex filifolia		**1**	**1**		**1**	2	1
Carex granularis Muhl. ex Willd.		**1**		**1**		1	1
Carex gravida var. gravida		**1**	**1**		**1**	2	1
Carex hallii		**1**			**1**	1	1
Carex heliophila		**1**	**1**		**1**	2	1
Carex hystericina Muhl. ex Willd.		**1**	**1**	**1**	**1**	2	2
Carex interior Bailey		**1**	**1**	**1**	**1**	2	2
Carex lacustris Willd.				**1**	**1**	0	2
Carex laeviconica Dewey		**1**	**1**		**1**	2	1
Carex lanuginosa Michx.		**1**	**1**		**1**	2	1
Carex meadii		**1**			**1**	1	1
Carex obtusata		**1**			**1**	1	1
Carex peckii					**1**	0	1
Carex praegracilis W. Boott		**1**	**1**		**1**	2	1
Carex prairea Dewey ex Wood		**1**			**1**	1	1
Carex pseudocyperus L.		**1**			**1**	1	1

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Carex retrorsa Schwein.			**1**		**1**	1	1
Carex rostrata Stokes		**1**	**1**		**1**	2	1
Carex sartwellii Dewey		**1**	**1**		**1**	2	1
Carex saximontana					**1**	0	1
Carex scirpiformis				**1**		0	1
Carex scoparia Schkuhr ex Willd.			**1**		**1**	1	1
Carex sprengelii		**1**	**1**	**1**	**1**	2	2
Carex stipata Muhl. ex Willd.		**1**	**1**	**1**	**1**	2	2
Carex stricta Lam.		**1**	**1**	**1**	**1**	2	2
Carex sychnocephala Carey		**1**	**1**		**1**	2	1
Carex tenera Dewey		**1**			**1**	1	1
Carex tetanica Schkuhr		**1**	**1**		**1**	2	1
Carex torreyi			**1**		**1**	1	1
Carex tribuloides				**1**		0	1
Carex viridula Michx.		**1**				1	0
Carex vulpinoidea Michx.		**1**	**1**	**1**	**1**	2	2
Carex xerantica		**1**			**1**	1	1
Catabrosa aquatica		**1**			**1**	1	1
Ceratophyllum demersum L.	**1**	**1**	**1**	**1**	**1**	3	2
Chenopodium glaucum L.	**1**	**1**	**1**	**1**	**1**	3	2
Chenopodium rubrum L.	**1**	**1**	**1**	**1**	**1**	3	2
Cicuta bulbifera L.		**1**			**1**	1	1
Cicuta maculata L.		**1**	**1**	**1**	**1**	2	2
Cinna arundinacea L.				**1**	**1**	0	2
Cinna latifolia (Trev. ex Goepp.) Griseb.		**1**		**1**	**1**	1	2
Circaea alpina L.				**1**	**1**	0	2
Cirsium muticum Michx.				**1**		0	1
Cleome serrulata		**1**	**1**		**1**	2	1
Cornus sericea ssp. sericea L.	**1**	**1**		**1**		2	1
Cornus stolonifera			**1**		**1**	1	1
Crepis runcinata	**1**	**1**	**1**		**1**	3	1
Cyperus aristatus			**1**		**1**	1	1
Cyperus engelmannii					**1**	0	1

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Cyperus erythrorhizos Muhl.				**1**	**1**	0	2
Cyperus esculentus L.		**1**			**1**	1	1
Cyperus rivularis				**1**	**1**	0	2
Cyperus schweinitzii		**1**			**1**	1	1
Cyperus strigosus L.				**1**		0	1
Cypripedium caleolus			**1**	**1**	**1**	1	2
Cypripedium candidum Muhl. ex Willd.		**1**	**1**		**1**	2	1
Cypripedium reginae Walt.			**1**		**1**	1	1
Deschampsia cespitosa (L.) Beauv.		**1**			**1**	1	1
Distichlis spicata (L.) Greene		**1**	**1**	**1**	**1**	2	2
Echinochloa crus-galli (L.) Beauv.	**1**			**1**		1	1
Echinochloa muricata (Beauv.) Fern.	**1**	**1**	**1**	**1**	**1**	3	2
Eleocharis acicularis (L.) Roemer & J.A. Schultes	**1**	**1**	**1**	**1**	**1**	3	2
Eleocharis compressa Sullivant					**1**	0	1
Eleocharis erythropoda Steud.		**1**			**1**	1	1
Eleocharis macrostachya		**1**	**1**		**1**	2	1
Eleocharis obtusa (Willd.) J.A. Schultes			**1**	**1**	**1**	1	2
Eleocharis parvula (Roemer & J.A. Schultes) Link ex Bluff, Nees & Sch				**1**	**1**	0	2
Eleocharis smallii Britt.		**1**	**1**		**1**	2	1
Elodea canadensis Michx.	**1**	**1**	**1**		**1**	3	1
Elymus riparius	**1**			**1**	**1**	1	2
Epilobium angustifolium subsp. circumvagum		**1**	**1**	**1**	**1**	2	2
Epilobium ciliatum Raf.		**1**				1	0
Epilobium coloratum Biehler				**1**	**1**	0	2
Epilobium leptophyllum Raf.	**1**	**1**	**1**	**1**	**1**	3	2
Equisetum arvense			**1**		**1**	1	1
Equisetum fluviatile L.			**1**	**1**	**1**	1	2
Equisetum hyemale L.		**1**	**1**	**1**	**1**	2	2
Equisetum pratense Ehrh.				**1**		0	1
Equisetum sylvaticum L.				**1**		0	1
Equisetum X ferrissii Clute (pro sp.)		**1**	**1**		**1**	2	1
Eragrostis cilianensis	**1**	**1**	**1**		**1**	3	1

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Eragrostis hypnoides (Lam.) B.S.P.	**1**	**1**			**1**	2	1
Eragrostis pectinacea					**1**	0	1
Eragrostis reptans (Michx.) Nees				**1**		0	1
Erigeron glabellus var. pubescens Hook.		**1**	**1**		**1**	2	1
Erigeron philadelphicus L.		**1**	**1**	**1**	**1**	2	2
Eriophorium polystachion		**1**			**1**	1	1
Eriophorum viridicarinatum (Engelm.) Fern.					**1**	0	1
Eupatorium maculatum var. maculatum L.		**1**	**1**	**1**	**1**	2	2
Eupatorium perfoliatum L.				**1**	**1**	0	2
Euthamia graminifolia var. graminifolia	**1**	**1**		**1**		2	1
Fraxinus nigra Marsh.				**1**		0	1
Fraxinus pennsylvanica	**1**	**1**	**1**	**1**		3	1
Galium obtusum Bigelow				**1**		0	1
Galium trifidum L.		**1**	**1**		**1**	2	1
Gentianella amarella (L.) Boerner		**1**			**1**	1	1
Gentiania affinis			**1**		**1**	1	1
Gentiania andrewsii			**1**		**1**	1	1
Gentiania puberulenta			**1**		**1**	1	1
Gentianopsis crinita (Froel.) Ma		**1**			**1**	1	1
Gentianopsis procera (Holm) Ma		**1**			**1**	1	1
Geum macrophyllum Willd.				**1**		0	1
Geum rivale L.				**1**		0	1
Glaux maritima L.		**1**			**1**	1	1
Glyceria borealis (Nash) Batchelder		**1**			**1**	1	1
Glyceria grandis S. Wats.		**1**	**1**	**1**	**1**	2	2
Glyceria striata (Lam.) A.S. Hitchc.		**1**	**1**	**1**	**1**	2	2
Gratiola neglecta Torr.				**1**		0	1
Habenaria hyperborea		**1**	**1**		**1**	2	1
Habenaria viridis		**1**	**1**		**1**	2	1
Helenium autumnale L.	**1**	**1**		**1**		2	1
Helianthus grosseserratus Martens				**1**	**1**	0	2
Helianthus nuttallii ssp. Rybergii		**1**	**1**		**1**	2	1
Heracleum sphondylium L.		**1**		**1**		1	1

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Heteranthera dubia			1		1	1	1
Hippuris vulgaris L.		1			1	1	1
Hypoxis hirsuta (L.) Coville		1	1		1	2	1
Impatiens capensis Meerb.	1	1	1		1	3	1
Iva axillaris			1		1	1	1
Iva xanthifolia		1	1		1	2	1
Juncus alpinus		1	1		1	2	1
Juncus balticus Willd.		1	1		1	2	1
Juncus bufonius L.		1	1		1	2	1
Juncus canadensis				1		0	1
Juncus dudleyi		1			1	1	1
Juncus interior Wieg.		1			1	1	1
Juncus longistylis Torr.		1	1		1	2	1
Juncus nodosus L.		1	1		1	2	1
Juncus torreyi Coville		1	1		1	2	1
Laportea canadensis		1			1	1	1
Lathyrus venosus Muhl. ex Willd.	1		1	1	1	2	2
Leersia oryzoides (L.) Sw.		1		1	1	1	2
Lemna minor L.	1	1	1	1	1	3	2
Lemna trisulca L.	1	1	1	1	1	3	2
Lilium philidelphicum		1	1	1	1	2	2
Lindernia dubia (L.) Pennell				1	1	0	2
Lippia cuneifolia				1		0	1
Lobelia kalmii L.		1			1	1	1
Lobelia siphilitica L.				1		0	1
Lycopus americanus Muhl. ex W. Bart.		1	1	1	1	2	2
Lycopus asper	1	1	1		1	3	1
Lycopus uniflorus Michx.			1		1	1	1
Lysimachia ciliata L.		1	1	1	1	2	2
Lysimachia hybrida		1	1		1	2	1
Lysimachia lanceolata			1		1	1	1
Lysimachia quadriflora Sims				1		0	1
Lysimachia thyrsiflora L.		1		1	1	1	2

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Lythrum salicaria L.				**1**	**1**	0	2
Marsilea vestita Hook. & Grev.		**1**	**1**		**1**	2	1
Mentha arvensis L.		**1**		**1**		1	1
Mimulus glabratus Kunth		**1**			**1**	1	1
Mimulus ringens L.		**1**	**1**	**1**	**1**	2	2
Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi			**1**		**1**	1	1
Muhlenbergia frondosa (Poir.) Fern.					**1**	0	1
Muhlenbergia glomerata (Willd.) Trin.		**1**			**1**	1	1
Muhlenbergia mexicana (L.) Trin.		**1**			**1**	1	1
Muhlenbergia racemosa (Michx.) B.S.P.		**1**	**1**		**1**	2	1
Myriophyllum exalbescens		**1**				1	0
Myriophyllum heterophyllum Michx.				**1**		0	1
Nuphar lutea (L.) Sm.				**1**	**1**	0	2
Nymphaea odorata Ait.				**1**		0	1
Nymphaea tuberosa					**1**	0	1
Oenothera flava (A. Nels.) Garrett				**1**		0	1
Onoclea sensibilis L.				**1**		0	1
Panicum capillare	**1**	**1**	**1**	**1**	**1**	3	2
Parnassia glauca Raf.		**1**			**1**	1	1
Parnassia palustris L.		**1**			**1**	1	1
Pedicularis canadensis					**1**	0	1
Pedicularis lanceolata Michx.		**1**	**1**		**1**	2	1
Penthorum sedoides L.				**1**	**1**	0	2
Phalaris arundinacea L.	**1**	**1**	**1**	**1**	**1**	3	2
Pharlaris carnariensis			**1**	**1**	**1**	1	2
Phragmites australis (Cav.) Trin. ex Steud.	**1**	**1**	**1**	**1**	**1**	3	2
Physostegia parviflora Nutt. ex Gray		**1**		**1**	**1**	1	2
Pilea pumila (L.) Gray	**1**			**1**		1	1
Plantago elongata Pursh					**1**	0	1
Plantago eriopoda Torr		**1**		**1**	**1**	1	2
Poa palustris L.		**1**	**1**	**1**	**1**	2	2
Polygonum amphibium L.	**1**	**1**		**1**	**1**	2	2
Polygonum coccineum	**1**		**1**	**1**	**1**	2	2

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Polygonum hydropiper L.				**1**	**1**	0	2
Polygonum hydropiperoides Michx.				**1**	**1**	0	2
Polygonum lapathifolium L.		**1**	**1**	**1**	**1**	2	2
Polygonum pensylvanicum L.				**1**	**1**	0	2
Polygonum persicaria L.	**1**		**1**	**1**	**1**	2	2
Polygonum punctatum Ell.				**1**	**1**	0	2
Polygonum ramosissimum Michx.		**1**		**1**	**1**	1	2
Polygonum sagittatum L.				**1**		0	1
Populus angustifolia James				**1**		0	1
Populus balsamifera L.		**1**		**1**		1	1
Potamogeton amplifolius Tuckerman					**1**	0	1
Potamogeton crispus L.				**1**		0	1
Potamogeton diversifolius Raf.				**1**	**1**	0	2
Potamogeton filiformis Pers.					**1**	0	1
Potamogeton gramineus L.			**1**		**1**	1	1
Potamogeton natans L.			**1**		**1**	1	1
Potamogeton nodosus Poir.					**1**	0	1
Potamogeton pectinatus L.	**1**	**1**	**1**	**1**	**1**	3	2
Potamogeton praelongus Wulfen					**1**	0	1
Potamogeton pusillus L.		**1**	**1**		**1**	2	1
Potamogeton richardsonii (Benn.) Rydb.		**1**	**1**		**1**	2	1
Potamogeton strictifolius Benn.					**1**	0	1
Puccinellia cusckii		**1**				1	0
Puccinellia nuttalliana (J.A. Schultes) A.S. Hitchc.		**1**	**1**		**1**	2	1
Ranunculus abortivus L.		**1**		**1**		1	1
Ranunculus acris L.				**1**		0	1
Ranunculus cymbalaria Pursh		**1**	**1**		**1**	2	1
Ranunculus fascicularis				**1**		0	1
Ranunculus flabellaris Raf.			**1**		**1**	1	1
Ranunculus gmelinii DC.		**1**	**1**		**1**	2	1
Ranunculus hispidus var. nitidus (Chapman) T. Duncan		**1**			**1**	1	1
Ranunculus longirostris Godr.		**1**			**1**	1	1
Ranunculus macounii Britt.		**1**	**1**		**1**	2	1

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Ranunculus pensylvanicus L. f.			**1**	**1**	**1**	1	2
Ranunculus recurvatus					**1**	0	1
Ranunculus rhomboideus		**1**			**1**	1	1
Ranunculus sceleratus L.		**1**	**1**	**1**	**1**	2	2
Ranunculus subrigidus		**1**	**1**		**1**	2	1
Ribes americanum P. Mill.	**1**	**1**	**1**	**1**	**1**	3	2
Ribes triste Pallas				**1**	**1**	0	2
Rorippa palustris (L.) Bess.	**1**	**1**	**1**	**1**	**1**	3	2
Rorippa truncata			**1**			1	0
Rotala ramosior (L.) Koehne				**1**		0	1
Rudbeckia laciniata	**1**	**1**	**1**	**1**	**1**	3	2
Rumex crispus L.	**1**	**1**		**1**	**1**	2	2
Rumex maritimus L.	**1**	**1**	**1**	**1**	**1**	3	2
Rumex orbiculatus Gray	**1**			**1**	**1**	1	2
Rumex stenophyllus Ledeb.		**1**			**1**	1	1
Ruppia maritima L.	**1**			**1**	**1**	1	2
Sagittaria cuneata Sheldon		**1**	**1**		**1**	2	1
Sagittaria latifolia Willd.	**1**	**1**	**1**	**1**	**1**	3	2
Salicornia rubra A. Nels.	**1**		**1**		**1**	2	1
Salix alba L.		**1**			**1**	1	1
Salix amygdaloides Anderss.	**1**	**1**	**1**	**1**	**1**	3	2
Salix bebbiana Sarg.	**1**	**1**	**1**		**1**	3	1
Salix candida Fluegge ex Willd.		**1**	**1**		**1**	2	1
Salix discolor Muhl.	**1**	**1**	**1**	**1**	**1**	3	2
Salix eriocephala Michx.		**1**		**1**		1	1
Salix exigua Nutt.	**1**	**1**	**1**	**1**	**1**	3	2
Salix humilis			**1**	**1**	**1**	1	2
Salix lucida Muhl.	**1**		**1**	**1**	**1**	2	2
Salix lutea Nutt.		**1**				1	0
Salix pentandra		**1**				1	0
Salix petiolaris Sm.		**1**		**1**		1	1
Sambucus canadensis	**1**	**1**	**1**	**1**	**1**	3	2
Sambucus racemosa subsp. pubens					**1**	0	1

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Scirpus acutus Muhl. ex Bigelow		**1**	**1**		**1**	2	1
Scirpus atrovirens Willd.	**1**	**1**		**1**	**1**	2	2
Scirpus cyperinus (L.) Kunth				**1**	**1**	0	2
Scirpus fluviatilis (Torr.) Gray		**1**	**1**	**1**	**1**	2	2
Scirpus heterochaetus Chase		**1**	**1**		**1**	2	1
Scirpus maritimus L.	**1**	**1**	**1**		**1**	3	1
Scirpus microcarpus J.& K. Presl	**1**	**1**	**1**	**1**	**1**	3	2
Scirpus nevadensis S. Wats.			**1**			1	0
Scirpus pallidus (Britt.) Fern.		**1**				1	0
Scirpus pungens Vahl	**1**	**1**		**1**		2	1
Scirpus validus	**1**	**1**	**1**	**1**	**1**	3	2
Scolochloa festucacea (Willd.) Link		**1**				1	0
Scutellaria galericulata L.		**1**	**1**		**1**	2	1
Scutellaria lateriflora L.		**1**		**1**	**1**	1	2
Scutellaria parvula					**1**	0	1
Selaginella densa			**1**		**1**	1	1
Selaginella rupestris					**1**	0	1
Senecio congestus (R. Br.) DC.		**1**	**1**		**1**	2	1
Senecio pseudaureus Rydb.		**1**	**1**		**1**	2	1
Silphium perfoliatum L.				**1**	**1**	0	2
Sium suave Walt.		**1**	**1**	**1**	**1**	2	2
Solidago gigantea Ait.		**1**	**1**	**1**	**1**	2	2
Sonchus asper (L.) Hill	**1**		**1**	**1**	**1**	2	2
Sparganium chlorocarpum		**1**	**1**	**1**	**1**	2	2
Sparganium eurycarpum Engelm. ex Gray		**1**	**1**		**1**	2	1
Spartina gracilis		**1**	**1**		**1**	2	1
Spartina pectinata Link	**1**	**1**	**1**	**1**	**1**	3	2
Sphenopholis obtusata		**1**	**1**		**1**	2	1
Spiraea alba Du Roi	**1**	**1**		**1**	**1**	2	2
Stachys palustris L.	**1**	**1**		**1**		2	1
Stachys tenuifolia Willd.				**1**		0	1
Suaeda depressa		**1**	**1**		**1**	2	1
Tamarix ramosissima Ledeb.				**1**		0	1

Table 3. Continued.

	Found at site			Found in RR Basin		Number of Sources	
Species	**Noted by Wiley 2001 at Devils Lake**	**Noted at Camp Grafton 1999-2000**	**Noted by AFGP in Ramsey/Benson Co.s**	**Noted by Wiley 2001 in Red River Basin**	**Noted AFGB in Red River Basin**	**Found in Devils Lake Basin**	**Found in Red River Basin**
Teucrium canadense L.	**1**	**1**	**1**	**1**	**1**	3	2
Thalictrum dioicum L.				**1**	**1**	0	2
Thalictrum venulosum Trel.		**1**	**1**	**1**	**1**	2	2
Triglochin maritimum L.		**1**	**1**		**1**	2	1
Triglochin palustre L.		**1**			**1**	1	1
Typha angustifolia L.		**1**	**1**	**1**	**1**	2	2
Typha latifolia L.		**1**	**1**	**1**	**1**	2	2
Typha X GLAUCA		**1**		**1**		1	1
Ulmus americana		**1**	**1**	**1**	**1**	2	2
Ulmus pumila		**1**	**1**	**1**	**1**	2	2
Urtica dioica L.			**1**	**1**	**1**	1	2
Utricularia intermedia Hayne		**1**				1	0
Utricularia vulgaris		**1**	**1**		**1**	2	1
Vallisneria americana Michx.				**1**	**1**	0	2
Verbena hastata L.		**1**	**1**	**1**	**1**	2	2
Vernonia fasciculata Michx.				**1**		0	1
Veronica americana Schwein. ex Benth.		**1**	**1**	**1**	**1**	2	2
Veronica anagallis-aquatica L.		**1**		**1**	**1**	1	2
Veronica peregrina L.		**1**	**1**		**1**	2	1
Viburnum lentago			**1**	**1**	**1**	1	2
Viola nephrophylla Greene		**1**		**1**	**1**	1	2
Zannichellia palustris L.		**1**	**1**	**1**	**1**	2	2
Zigadenus elegans		**1**	**1**	**1**	**1**	2	2
Zizania aquatica L.		**1**	**1**	**1**	**1**	2	2
Total Wetland Species in Eastern North Dakota	59	218	179	179	285		

Table 4. Protozoa of Stump Lake (SL) and Devils Lake (DL).

Taxon	SL	DL	Taxon	ESL	DL
Acineta unknown 1	X	X	*Holosticha vernalis*		X
Acineta unknown 2	X		*Lacrymaria cohnii*	X	
Actinophrys sol		X	*Lacrymaria lagenula*		X
Amoeba guttula		X	*Lacrymaria olor*		X
Amoeba limax		X	*Lacrymaria truncaum*		X
Amoeba proteus		X	*Lionotus fasciola*	X	X
Amoeba radiosa		X	*Lionotus* sp.		X
Amoeba sp.		X	*Loxocephalus granulosus*		X
Amoeba striata		X	*Mesodinium pulex*		X
Amoeba verrucosa		X	*Metopus es*		X
Amphileptus meleagris	X	X	*Monas* sp.		X
Anisonema grande		X	*Nassula ornata*		X
Arcella vulgaris		X	*Nassula rubens*		X
Aspidisca costata		X	*Notosolenus* sp.	X	X
Astasia tricophora		X	*Oxytricha bifaria*		X
Carchesium epistylis		X	*Oxytricha fallax*		X
Cercomonas (longicauda?)	X		*Oxytricha pellionella*		X
Chaenea teres		X	*Oxytricha* sp.		X
Chilodonella caudata		X	*Paramecium caudatum*		X
Chilodonella cucullulus		X	*Paramecium trichinum*		X
Chilophrya labiata		X	*Petalomonas mediocanellata*		X
Colpidium sp.		X	*Petalomonas* sp.		X
Cothurnia curva		X	*Pleuronema chrysalis*	X	X
Cothurnia imberbis	X	X	*Pleurotricha lanceolata*		X
Cyclidium glaucoma		X	*Podophrya libera*		X
Cyclidium litomesum		X	*Prorodon edentatus*		X
Cyphoderia ampulla		X	*Spathidium spatula*		X
Didinium nasutum		X	*Sphaerophrya magna*	X	X
Difflugia constricta		X	*Spirostomum ambiguum*		X
Difflugia pyriformis		X	*Stentor* sp.		X
Dysteria pusilla		X	*Stylonychia notophora*		X
Enchelys sp.		X	*Tachysoma parvistyla*	X	
Epistylis branchiophila		X	*Tetrahymena patula*		X
Epistylis plicatilis		X	*Tillina saprophila*		X
Euglypha alveolata		X	*Trepomonas agilis*		X
Euplotes charon		X	Trimastigidae unknown		X
Euplotes patella	X	X	*Uroleptus agilis*		X
Frontonia leucas		X	*Uroleptus rattulus*		X
Gerda sp.		X	*Vaginicola crystallina*	X	X
Glaucoma scintillans		X	*Vorticella convallaria*		X
Glaucoma sp.	X	X	*Vorticella microstoma*		X
Halteria grandinella		X	*Vorticella octava*		X
Heteromita globosa		X	*Vorticella telescopica*		X
Heteromita sp.		X	*Vorticella* unknown 1		X
Heteronema acus		X	*Vorticella* unknown 2		X
Histriculus erethisticus		X	*Zoothamnion* sp.	X	X
Holophrya ovum		X	*Zoothamnium alterans*	X	

Source: Young 1924.

Table 5. Collection locations of invertebrates classified as Candidate PBOC, with citations to sources listed below table. (Location codes: SL=Stump Lake, DL=Devils Lake, US=Upper Sheyenne River, LA=Lake Ashtabula, LS=Lower Sheyenne River, RR=Red River of the North, LW=Lake Winnipeg, LWB=Lake Winnipeg Basin, CL=Cottonwood Lakes area (Missouri River drainage).

TAXON	SL	DL	US	LA	LS	RR	LW	LWB	CLA
Phylum Rotifera	7								
Asplancha sp.		13						16	
Asplanchna silvestris		15							
Atrochus tentaculatus		13							
Brachionus calyciflorus pala		15							
B. capsuliflorus quadridentatus	15	15							
Brachionus dolabratus		15							
Brachionus havanaensis		13							
Brachionus plicatilis	15	15							
Brachionus plicatilis spatiosus	15	15							
Brachionus pterodinoides		6,15							
Brachionus satanicus	15	15							
Brachionus sp.	7	6,7							
Brachionus urceolaris		6,15						16	
Cephalodella catellina		15							
Cephalodella megalocephala		15							
Cephalodella sterea		15							
Collotheca cornuta		15							
Colurella adriatica		15							
Colurella colurus		15							
Filinia longiseta		6,15							
Hexarthra sp.	7								
Hexarthra fennica		15							
Keratella cochlearis		6,15							
Keratella quadrata	15	6,15							
Lecane sp.		13							
Lecane inermis		15							
Lecane luna	15	15							
Lepadella sp.		13							
Lepadella patella		15							
Monostyla bulla	15	15							
Monostyla cornuta		15							
Monostyla lunaris		15						16	
Monostyla quadridentata		15							
Mytilina ventralis brevispina		15							
Notholca acuminata		13							
Notholca striata		15							
Notommatidae unknown		13							
Philodina sp.		13							
Platyias quadricornis	15	15							

Table 5. Continued.

TAXON	SL	DL	US	LA	LS	RR	LW	LWB	CLA
Ptygura sp.		15							
Squatinella mutica		15							
Testudinella patina		15							
Trichocerca sp.		13							
Phylum Gastrotricha									
Chaetonotus maximus		15							
Phylum Platyhelminthes									
Gyratrix hermaphroditus		15							
Phylum Nematoda									
Achromadora sp.		15							
Cephalobus sp.		15							
Chromadora sp.		15							
Diplogaster sp.		15							
Dorylaimus unknown 1		15							
Dorylaimus unknown 2		15							
Ironus sp.		15							
Monohystera unknown 1		15							
Monohystera unknown 2		15							
Plectus sp.		15							
Phylum Annelida									
Hirudinea		11		10		5			
Oligochaeta		11				5			
Phylum Mollusca									
Stagnicola caperata		1	14		4	1			
Stagnicola elodes		1	14			1			
Phylum Arthropoda									
Cladocera	7,11	11							
Alona sp.		13					8,9	16,18	17
Alona rectangula		11,15							
Bosmina hagmanni		13							
Bosmina longirostris		15				19	9	16,18	
Ceriodaphnia pulchella		15						18	
Ceriodaphnia quadrangula		6				19	12,16	16	17
Chydorus sphaericus		6,15					9	16,18	17
Daphnia sp.	11	11,13				19	9,12	16,18	
Daphnia galeata mendotae		13	14	10		19	9	18	
Daphnia longispina		15					9	16	
Daphnia magna		15						16	

Table 5. Continued.

TAXON	SL	DL	US	LA	LS	RR	LW	LWB	CLA
Daphnia pulex	11	6,11,15	14	10		19	12	16	17
Daphnia schoedleri		13				19	9	18	
Daphnia similis	11	6,11							17
Diaphanosoma birgei		6							
Diaphanosoma brachyurum		15						16	
D. leuchtenbergiannum		11				19	9	16	
Moina affinis		6							
Moina macrocopa	15	15						16	
Simocephalus vetulus		15					16		17
Copepoda	11	11							
Acanthocyclops robustus		13							
Acanthocyclops vernalis		13					9		
Aglaodiaptomus clavipes		6							
Cletocampus albuquerquensis	11	11,15							17
Cyclops viridis americanus		15					9		
Cyclops leuckarti		15							
Cyclops serrulatus		15					9, 16		
Diacyclops navus		13							
Diacyclops thomasi		13					9		
Diaptomus sp.	11	11					9,12		
Diaptomus leptopus piscinae		15					9	16	
Diaptomus nevadensis	11	11							
Diaptomus shoshone		15							
Diaptomus sicilis	11	6,11,15					9	16	17
Diaptomus siciloides	15	15				19	12		
Harpacticoida	7,11	13						16	
Hesperodiaptomus sp.		13							
Hesperodiaptomus nevadensis		6							
Laophonte sp.		15						16	
Macrocyclops albidus		13							
Mesocyclops edax		11				19	9	16	
Ostracoda	7	11							
Cypris pellucida		15							
Anostraca - *Artemia salina*	7,11								
Conchostraca - unknown species		11,13							
Amphipoda									
Hyalella azteca	11	11,15				5	3		
Gammarus sp.		11					3		
Gammarus lacustris		13					3		

Table 5. Continued.

TAXON	SL	DL	US	LA	LS	RR	LW	LWB	CLA
Insecta									
Anisoptera	7								
Sympetrum corruptum	15								
Zygoptera	7,15	11,15							
Enallagma sp.		15				5			
Corixidae		11				5			
Arctecorixa sp.	15	15							
Corixa sp.	15	13,15							
Notonectidae									
Buenoa margaritacea		15							
Notonecta sp.		15							
Notonecta undulata		15							
Trichoptera	7,11	11				5			
Limnephilus rhombicus		13,15							
Phryganea sp.		15							
Triaenodes flavescens		15							
Ephemeroptera		11				5			
Coleoptera		11				5			
Agabus sp.		15							
Berosus sp.		15							
Bidessus lacustris		15							
Deronectes sp.	15	15							
Enochrus sp.	15	15				5			
Hydrophilus triangularis		15							
Hygrotus unknown 1		15							
Hygrotus unknown 2		15							
Hygrotus nubilus		15							
Ochthebius sp.	15	15							
Tropisternus sp.		15				5			
Ceratopogonidae	7	11				5			
Chaoboridae - *Chaoborus* sp.		15							
Chironomidae	7,11	11				5			
Chironomus sp.		15							
Procladius sp.		15		10					
Protenthes punctipennis		15							
Tanypus sp.		15							
Dolichopodidae	7					5			
Ephydridae	7								
Ephydra sp.		15							
Stratiomyidae						5			
Nemotelus sp.		15							
Odontomyia sp.	15	15							
Stratiomyia sp.	15	15				5			
Syrphidae						5			

Table 5. Continued.

TAXON	SL	DL	US	LA	LS	RR	LW	LWB	CLA
Eristalis tenax		15							
Tabanidae	7								
Chrysops sp.		15				5			
Tabanus sp.		15				5			
Hydracarina		11,15				5			
Diplodontus despiciens		15							
Eylais sp.		15							
Hydrachna schneideri		15							
Hydrachna sp.		15							
Hydrachna valida		15							
Hydryphantes sp.		15							

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Table 6. Fishes of Devils Lake and their occurrences in the Upper Sheyenne River (US), Lake Ashtabula (LA), and Lower Sheyenne River (LS).

SPECIES	COMMON NAME	OTHER LOCATIONS
Catastomus commersoni	white sucker	US, LA, LS, RRN, LW
Culaea inconstans	brook stickleback	all sites
Esox lucius	northern pike	all sites
Esox masquinongy	muskellunge	LS, RRN
E. luciusXmasquinongy[1]	tiger muskie	none
Ictalurus melas	black bullhead	US, LA, LS, RRN
Morone chrysops	white bass	all sites
Morone saxatilis[2]	striped bass	none
Perca flavescens	yellow perch	all sites
Pimephales promelas	fathead minnow	all sites
Pomoxis nigromaculatus	black crappie	all sites
Stizostedion vitreum	walleye	all sites

Sources: DLWG 1996; Peterka and Koel 1996.

[1]stocked; non-reproducing sterile hybrids
[2]sustained presence in Devils Lake uncertain; reproduction appears highly unlikely

Table 7. Fish parasites of Devils Lake, their hosts, and their occurrences in the Upper Sheyenne River (US), Lake Ashtabula (LA), and Lower Sheyenne River (LS).

SPECIES	HOSTS	OTHER LOCATIONS
Monogenea		
Gyrodactylus hoffmani	*P. promelas*	none recorded
Digenea		
Diplostomum spathaceum	*M. chrysops*	US,LA,LS
Neascus sp.	*P. promelas* *M. chrysops*	US,LA,LS
Cestoidea		
Ligula intestinalis	*P. promelas* *E. lucius* *S. vitreum*	none recorded
Proteocephalus pinguis	*E. lucius*	US,LA,LS
Proteocephalus sp.	*C. commersoni* *P. flavescens* *M. chrysops* *E. lucius*	US,LA,LS
Nematoda		
Contracaecum spiculigerum	*M. chrysops*	US,LA,LS
Acanthocephala		
Rhadinorhynchus sp.	*P. flavescens* *M. chrysops* *S. vitreum*	none recorded

Sources: Forstie and Holloway 1984; Reinisch 1981; Sutherland and Holloway 1979.

Table 8. Devils Lake taxa classified as Potential Biota of Concern (PBOC).

ALGAE	
Chlorophyta	
Ankistrodesmus falcatus falcatus	*Keratococcus* sp.
Ankyra judayi	*Kirchneriella contorta*
Botryococcus braunii	*Kirchneriella elongata*
Chlorella sp.	*Kirchneriella subsolitaria*
Chlorella vulgaris	*Monoraphidium mirabile*
Chlorococcum sp.	*Nannochloris* sp.
Chlorogonium sp.	*Nephrocytium limnetica*
Choricystis minor	*Nephrocytium naegelii*
Cladophora crispata	*Nephrocytium* sp.
Cladophora fracta	*Oocystis crassa*
Cladophora glomerata var. keutzingiana	*Oocystis gloecystiformis*
Cladophora keutzingiana	*Oocystis naeglii*
Cladophora sp.	*Oocystis novae-semliae v. maxima*
Clathrocystis aeruginosa	*Oocystis pyriformis*
Closterium acutum	*Oocystis submarina*
Closterium dianae arcuatum	*Pandorina* sp.
Closterium parvulum var. angustissima	*Pascherina tetras*
Closterium pronum	*Pediastrum angulosum*
Closterium subcostatum	*Pediastrum* sp.
Coccomonas sp.	*Protoderma viride*
Coccomyxa sp.	*Pseudosphaerocystis lacustris*
Coenochloris pyrenoidosa	*Pseudoulvella* sp.
Coenochloris sp.	*Scenedesmus bijugatus*
Cosmarium scopularum	*Scenedesmus granulatus*
Cosmarium sub-costatum	*Scenedesmus intermedius*
Dunaliella sp.	*Scenedesmus linearis*
Dunaliella viridis	*Scenedesmus opoliensis*
Dysmorphococcus sp.	*Scenedesmus quadricauda typicus*
Elakatothrix gelatinosa	*Scenedesmus subspicatus*
Elakatothrix viridis	*Schroederia judayi*
Enteromorpha intestinalis	*Stephanoptera gracilis*
Enteromorpha prolifera	*Stichococcus* sp.
Enteromorpha sp.	*Stigeoclonium attenuatum*
Gloecoccus sp.	*Stigeoclonium nanum*
Gloeocystis major	*Ulothrix aequalis*
Gongrosira sp.	*Vaucheria* sp.
Kentrosphaeria sp.	*Zoochorella conductrix*

Table 8. Continued.

Chrysophyta; Order Bacillariophyceae	
Achnanthidium clevei	*Navicula tryblionella*
Achnanthidium microcephalum	*Navicula vaucheriae*
Amphora proteus	*Navicula ventosa*
Anomoeoneis serians	*Neidium iridis*
Cymbella turgida; a.k.a. C. elginsis;	*Nitzschia adapta*
Encyonema turgidum	*Nitzschia angustata*
Caloneis bacillaris var. thermalis	*Nitzschia attenuata*
Campylodiscus clypeus	*Nitzschia commutatoides*
Catacombus gaillonii	*Nitzschia gandersheimiensis*
Cavinicula lacustris	*Nitzschia halophila*
Chaetoceros muelleri	*Nitzschia lanceolata*
Craticula ambigua	*Nizschia stagnorum*
Craticula cuspidata	*Pinnularia brebissoni*
Ctenophora pulchella	*Pinnularia major*
Cyclostephanos dubius	*Pinnularia stauroptera*
Cyclotella pediculus	*Pinnularia subcapitata*
Cyclotella radiosa	*Planothidium delicatulum*
Cymbella aequalis	*Planothidium lanceolatum*
Cymbella affinis	*Rhopalodia gibba var. ventricosa*
Epithemia ocellata	*Scoliopleura peisonis*
Fallacia pygmaea	*Staurosira construens*
Gomphonema brebissonii	*Stephanodiscus corconensis*
Gomphonema montanum	*Stephanodiscus rotula*
Lemnicola hungarica	*Surirella fastuosa*
Navicula agnewii	*Surirella peisonis*
Navicula capitata var. capitata	*Surirella robusta*
Navicula crucicula	*Surirella striatula*
Navicula fonticula	*Synedra amphicephala*
Navicula gastrum	*Synedra montana*
Navicula miniscula	*Tabularia tabulata*
Navicula minnewaukonensis	*Thalassiosira bramaputrae*
Navicula navicularis	*Tryblionella hungarica*
Navicula scandinavica	*Tryblionella hungarica*
Navicula subminiscula	*Tryblionella tryblionella*

Table 8. Continued.

Chrysophyta; Order Chrysophyceae	
Bicosoeca sp.	*Kephyrion impletum*
Chrysamoeba radians	*Kephyrion planktonicum*
Chrysocapsa vernalis	*Kephyrion skujae*
Chrysococcus ornatus	*Ochromonas fragilis*
Kephyrion globosum	*Synura* sp.
Chrysophyta; Order Xanthophyceae	
Characiopsis cylindrica	*Sorastrum spinulosum*
Characiopsis subulata	*Spermatozoopsis* sp.
Odontidium elongatum	*Sphinctocystis librilis*
Cryptophyta	
Cryptochrysis commutata	*Rhodomonas rubra*
Cryptomonas curvata	
Cyanobacteria	
Anabaena spiroides	*Oscillatoria amphibia*
Anabaenopsis elenkinii	*Oscillatoria brevis*
Anacystis nidulans	*Oscillatoria chalybea*
Anacystis saxicola	*Oscillatoria chlorina*
Anacystis unknown sp.	*Oscillatoria geminata*
Aphanocapsa delicatissima	*Oscillatoria hamelii*
Aphanocapsa elachista	*Oscillatoria janthiphora*
Aphanocapsa elachista var. coferta	*Oscillatoria nigra*
Aphanocapsa sp.	*Oscillatoria subtilissima*
Aphanothece castagnei	*Oscillatoria tenuis var. tergestina*
Arthrospira jenneri	*Phormidium mucicola*
Chroococcus minutus	*Planktolyngbya subtilus*
Chroococcus turgidus	*Plectonema tenue*
Coelosphaerium collinsii	*Pseudabaena mucicola*
Coelosphaerium dubium	*Rhabdoderma irregulare*
Dactylococcopsis acicularis	*Rhabdoderma sigmoidea*
Dactylococcopsis fascicularis	*Rhabdoderma sigmoidea f. minor*
Dactylococcopsis irregularis	*Rhabdogloea ellipsoidea*
Gloeocapsa lacustris var. compacta	*Spirulina major*
Gloetrichia natans	*Spirulina norstedtii*
Gomphosphaeria aponina cordiformis	*Spirulina subtilissima*
Lyngbya contorta	*Spirulina tenerrima*
Marssoniella sp.	*Synechococcus* sp.
Merismopedia convoluta	*Tetrapedia gothica*
Microspora loefgrenii	*Tetrapedia* sp.
Nodularia spumigena	*Tolypothrix lan*

Table 8. Continued.

Euglenophyta	
Euglena elongata	*Euglena proxima*
Euglena polymorpha	
VASCULAR PLANTS	
Butomus umbellatus	*Myriophyllum aquaticum*
Cabomba caroliniana	*Myriophyllum spicatum*
Crassula helmsii	non-native *Nymphaea* spp.
Hydrocharis morsus-ranae	*Potamogeton crispus*
Hydrilla verticillata	*Salvinia molesta*
Hygrophila polysperma	*Stratiotes aloides*
Lagarosiphon major	*Trapa natans*
Lythrum salicaria, L. virgatum	
INVERTEBRATES	
Rotifera	
Asplanchna silvestris	*Keratella cochlearis*
Atrochus tentaculatus	*Keratella quadrata*
Brachionus calyciflorus pala	*Lecane* sp.
B. capsuliflorus quadridentatus	*Lecane inermis*
Brachionus dolabratus	*Lecane luna*
Brachionus havanaensis	*Lepadella* sp.
Brachionus plicatilis	*Lepadella patella*
Brachionus plicatilis spatiosus	*Monostyla bulla*
Brachionus pterodinoides	*Monostyla cornuta*
Brachionus satanicus	*Monostyla quadridentata*
Brachionus sp.	*Mytilina ventralis brevispina*
Cephalodella catellina	*Notholca acuminata*
Cephalodella megalocephala	*Notholca striata*
Cephalodella sterea	Notommatidae unknown
Collotheca cornuta	*Philodina* sp.
Colurella adriatica	*Platyias quadricornis*
Colurella colurus	*Ptygura* sp.
Filinia longiseta	*Squatinella mutica*
Hexarthra sp.	*Testudinella patina*
Hexarthra fennica	*Trichocerca* sp.
Nematoda	
Achromadora sp.	*Dorylaimus* unknown 2
Cephalobus sp.	*Ironus* sp.
Chromadora sp.	*Monohystera* unknown 1
Diplogaster sp.	*Monohystera* unknown 2
Dorylaimus unknown 1	*Plectus sp.*

Table 8. Continued.

<u>Arthropoda</u>	
Cladocera	
Alona rectangula	*Daphnia similis*
Bosmina hagmanni	*Diaphanosoma birgei*
Bythotrephes cederstroemi	*Moina affinis*
Copepoda	
Acanthocyclops robustus	*Diaptomus nevadensis*
Aglaodiaptomus clavipes	*Diaptomus shoshone*
Cletocampus albuquerquensis	*Hesperodiaptomus sp.*
Cyclops leuckarti	*Hesperodiaptomus nevadensis*
Diacyclops navus	*Macrocyclops albidus*
Ostracoda - *Cypris pellucida*	**Conchostraca** - unknown species
Anostraca - *Artemia salina*	**Decapoda** - *Orconectes rusticus*
<u>Gastrotricha</u>	**<u>Platyhelminthes</u>**
Chaetonotus maximus	*Gyratrix hermaphroditu*
<u>Mollusca</u>	
Cipangopaludina spp.	*Dreissena polymorpha*
FISHES	
Alosa pseudoharengus	*Mylopharyngodon piceus*
Carassius auratus	*Neogobius melanostomus*
Ctenopharyngodon idella	*Osmerus mordax*
Cyprinus carpio	*Petromyzon marinus*
Gymnocephalus cernuus	*Scardinius erythrophthalmus*
Hypophthalmichthys molitrix	*Stizostedion lucioperca*
Hypophthalmichthys nobilis	*Tilapia* spp., *Oreochromis* spp.,
Morone americana	*Sarotheradon melanotheron*
Morone saxatilis	
FISH PARASITES	
Gyrodactylus hoffmani	*Ligula intestinalis*
Rhadinorhynchus sp	
FISH PATHOGENS	
Heterosporis Schubert (species unknown), the protozoan "Yellow Perch Parasite"	
Infectious Pancreatic Necrosis Virus (IPNV)	
Infectious Hemotopoietic Necrosis Virus (IHNV)	
Largemouth Bass Virus (LMBV)	
Myxobolus cerebralis Hofer, the protozoan pathogen of whirling disease, and its intermediate invertebrate host *Tubifex tubifex* Müller, an annelid worm	
Parasites of striped bass	
Renibacterium salmoninarum Sanders and Fryer, Bacterial Kidney Disease (BKD)	

Table 9. Algae PBOC species characteristics used in selection/deselection decisions. All listed species have been reported in Devils Lake.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Anabaena spiroides	S. Great Lakes Region (Wisc.) (3). S. Present in New Zealand (5). S. Present in Illinois (6).	G. Aquatic - not usually found in temporary pools. Often forms a single species community(2). G. *Anabaena* remain suspended throughout the water and do not form surface scums. Reportedly responsible for the death of cattle and other animals that drink the water in which plants have developed profusely. Genus reportedly releases toxins into water where it is present(8).	
Anabaenopsis elenkinii	S. Great Lakes Region (Mich.)(3).	G. Plankton alga (2) euplanktonic(8).	
Anacystis nidulans	S. Present in Lago Canteras and Lago Rodó, Montevideo, Uruguay (14).	G. Generally found growing on damp rocks(2). Common to eutrophic Lakes.	S. Now generally referred to as *Synechococcus leopoliensis*(44).
Anacystis saxicola	No species information found.	G. Generally found growing on damp rocks(2)	
Aphanocapsa delicatissima	S. present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7). S. Common in the tychoplankton of many lakes(Mich. And Wisc.)(3).	G. Generally Aquatic - floating or adhering to submerged vegetation or rocks (2). Most frequent in soft or acid water (3). Comprises a regular part of the communities of seasonal and semi-permanent wetlands of a variety of Sedge, cattail and bullrush associations (7).	
Aphanocapsa elachista var. *conferta*	S. Species (no mention of variety) present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). S. Rare to common in several soft water lakes (Mich. And Wisc.)(3).	G. Floating(2)	
Coelosphaerium collinsii	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). S. Present in Illinois(6).	G. Widely distributed genus - important "water bloom" component (2). Found in Semi-permanent waters.	
Dactylococcopsis acicularis	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). S. Rather rare but found in several lakes (Wisc.)(3).	No species information found.	
Dactylococcopsis fascicularis	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7).	No species information found.	
Gloecapsa lacustris var. *compact*	No species information found.	G. Typically grows on damp rocks (2). G. Common to moist rocks and cliffs, greenhouse soil, moist cement, etc…(8).	
Marsoniella elegans	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). G. found in the North Central States(2).	G. Open water plankton (8).	

Table 9. Continued.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Microspora sp.	G. Found in bogs, swamps, ditches and soft water lakes. Usually shallow water bodies (3) G. Present in Illinois(6).	G. Common to ditches and pools - esp. in cooler months(2). Aquatic(8).	
Nodularia spumigena	S. Uncommon, found among algae of especially hard water: also adhering to the culms of rushes submerged in shallow water (Wisc.)(3) S. Present in Illinois(6). The most common species of four reported in this genera in the United States(8).	G. Aquatic of pools and ditches(2).	
Oscillatoria hamelii	S. Forming on dead leaves in a stream (Wisc.)(3).	S. Forms on dead leaves in a stream(3). G. Very ubiquitous-40+ species in U.S.(2) G. Forms in both water and soil, dripping rocks(8).	G. Some species within this genus are considered heatotoxic(poisonous to the liver and related systems) in higher organisms(43)
Oscillatoria nigra	S. Common in shallow waters of many lakes and ponds (Wisc.)(3).	G. Very ubiquitous - 40+ species in U.S.(2) G. Forms in both water and soil, dripping rocks(8).	G. Some species within this genus are considered heatotoxic(poisonous to the liver and related systems) in higher organisms(43)
Oscillatoria subtilissima	S. Present in the Baltic Sea(15,16).	G. Very ubiquitous - 40+ species in U.S.(2) G. Forms in both water and soil, dripping rocks(8).	G. Some species within this genus are considered heatotoxic(poisonous to the liver and related systems) in higher organisms(43)
Oscillatoria tenuis var. *tergestina*	S. Euplanktonic and tychoplanktonic (Wisc.)(3).	G. Very ubiquitous 40+ species in U.S.(2) G. Forms in both water and soil, dripping rocks(8).	G. Some species within this genus are considered heatotoxic(poisonous to the liver and related systems) in higher organisms(43)
Phormidium mucicola	S. Rather common in hard water: euplanktonic (Mich. And Wisc.)(3).	G. Subaerial in habit, usually in extensive patches on moist rocks and damp soil, 25+ species in U.S. (2).	
Planktolyngba subtilus	No species information found.	No species information found.	
Pseudabaena mucicola	No species information found.	No species information found.	
Rhabdoderma irregulare	S. present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7). Euplankter: in semi-hard water lakes(Wisc.)(3).	G. Only known from the plankton (2).	
Rhabdoderma sigmoidea	S. *R.siamoidea* present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7).	G. Only known from the plankton (2).	
Rhabdoderma sigmoidea f. *minor*	S. *R. siamoidea* var. *minor* present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7). Euplankter; (Wisc.)(3).	G. Only known from the plankton (2).	
Rhabdogloea ellipsoidea	S. present in the Baltic Sea. (16).	No species information found.	

Table 9. Continued.

Species Name	**Geographic distribution (S.=species, G.=genus)**	**Habitat (S.=species, G.=genus)**	**Taxonomy notes for PBOC algae species (S.=species, G.=genus)**
Spirulina major	S. present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7). Commonly found among *Oscillatoria* species on soil from which water has recently subsided, or on muddy shores and margins of springs, etc. (Wisc.)(3) S. Present in Illinois(6).	G. Fresh and salt water species (2).	
Synechococcus sp.	G. Multiple *Synechococcus* sp. present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7).	G. Twelve species recorded in the country(1950), all but one, *S. aeruginosus* are known only from hotsprings in Yellowstone National Park(2).	
Chrysophyta; order Chrysophyceae			
Chrysamoeba radians	S. Reported from various localities in the United States(2). S. Wisc., Mich.(3).	S. Rare, in euplankton(3)	
Chrysocapsa vernalis	G. Wisc and Mich(3). S. Present in Poland frog spawn(17).	G. Free-floating colonies of many lakes, both hard and soft water(3). S. Present in Polish frog spawn(17).	
Chrysococcus ornatus	G. Widely distributed in drainage basins of Ohio. No species information found.	G. Drainage basins of Ohio River and has been found in a few other localities. No species information found.	
Kephyrion globosum	No species information found.	No species information found.	Only one species is mentioned in the texts, Kephyrion has been found in Ohio and Alabama(2). S. reported from various reservoirs in Japan(Ito).
Kephyrion impletum	No species information found.	No species information found.	
Kephyrion planktonicum	No species information found.	No species information found.	
Kephyrion skujae	No species information found.	No species information found.	
Ochromonas fragilis	No species information found.	No species information found.	Prescott(8) suggests this may genus be referrable to *Chlorochromonas.*
Chrysophyta: order Xanthophyceae			
Characiopsis cylindrica	S. Wisc.(3) G. About a dozen species found in U.S. (2).	S. Epizoic on Daphnia and other microzoa in small lakes(3). G. Oil is formed rather than starch as a food reserve(8).	
Characiopsis subulata	G. About a dozen species found in U.S. (2). No species information found.	G. Oil is formed rather than starch as a food reserve(8).	
Chrysophyta order Bacillariophyceae			

Table 9. Continued.

Species Name	**Geographic distribution (S.=species, G.=genus)**	**Habitat (S.=species, G.=genus)**	**Taxonomy notes for PBOC algae species (S.=species, G.=genus)**
Achnanthes clevei	S. Found in entire United States(4). S.Great Lakes(11). S. Reported in Missouri(13).	S. Common in lakes and rivers at higher pH values (alkaliphil) (4). G. Subaerial, mostly marine(1). G. freshwater(9).	
Amphiprora sp.	G. Most species found in coastal waters. Amphiprora ornata is found throughout the continent(4) G.Great Lakes(11).	G. Ususally brackish marine, occasionally fresh water species (1). Often a benthic genus(4). G. May be free floating or adhere to mucilate on moist substrates(8).	Taxonomy is disputed. Round suggests that *Entomoneis* is the current and accepted genus name(1). *Amphiprora navicularis*, referred to as *Navicula semen* in Patrick and Reimer(4) as *Navicula semen* is found in cool water of low mineral content, sometimes and aerophil of Eastern half of United States to New Mexico.
Amphora momoeoneis sphaerophora	No species information found.	G. Mainly marine, a few freshwater species(1).	
Amphora serians	No species information found.	G. Mainly marine, a few freshwater species(1).	
Caloneis bacillaris var. *thermalis*	S. Nebraska(4). S. Present in Illinois(6, 10). S. Great Lakes(11). S. Present in Montana(12). S. Reported in Nebraska(13).	S. Found in water of high mineral content(4). G. *Pinnularia*- mostly freshwater, freshwater species strongly dorsiventral(1).	Taxonomy is disputed. Round suggests that Pinnularia is the current and accepted genus name(1).
Catacombus gaillonii	S. Great Lakes(11).	G. Strictly marine(1).	
Chaetoceros muelleri	S. Present in Argentina. (18). Present in US southwest (48). S. Great Lakes(11). S. Present in Montana(12).	G. Mostly marine(1).	
Coscinodiscus lacustris	S. Great Lakes(11).	G. Mostly marine – freshwater lake species in high conductivity waters. Widely distributed in fossil record(1). Common within blue-green algal blooms(8). S. Freshwater(9).	
Craticula ambigua	S.Great Lakes(11).	G. Freshwater to brackish-epipelic(1).	
Cyclotella pediculus	No species information found.	G. Mainly freshwater(1). Planktonic, often occuring with *Stephanodiscus*(8).	
Cymatopleura sp.	S. Present in Illinois(10). G. Present in Illinois(6). G. Great Lakes(11).	G. Freshwater - tendency toward high conductivity (alkaline) waters(1). Both fresh water and marine(8). Planktonic (9).	
Diatoma tenue var. *tenue*	S. New England States, East Central States, Kansas(4). S. Present in Illinois(10). Species, not var. listed in Great Lakes(11).	S. In lakes or standing water: often found in water with relatively high conductivity or slightly salty(4). G. Strictly freshwater to only slightly saline(1).	
Gomphonema brebissoni	S. Entire United States area(4). S. Present in Montana(12).	S. Seems to prefer circumneutral water(4). G. Common to freshwater heptobenthic communities (1).	
Melosira granulata var. *angustissima*	S. Species, (unknown if variety) present in Illinois(6). S. Variety Present in Illinois(10). S.Great Lakes(11). S. Present in Montana(12).	S. Freshwater (9). G. Freshwater and marine epibenthic(1).	

Table 9. Continued.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Navicula accomoda	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). S. Eastern 1/2 of the United States(4) S. Great Lakes(11). S. Present in Montana(12).	S. Grows well in the presence of organic pollution(4). G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	
Navicula agnewii	No species information found.	No species information found.	
Navicula fonticula	S. *Navicula fontinalis* is found throughout the U.S.(4).	S. Navicula fontinalis is found in soft, hard or slightly brackishwater, lakes, rivers, bogs. Often found in standing alkaline waters(4). G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	*Navicula fontinalis* is described in Patrick and Reimer(4) under the name Caloneis bacillum. Due to the disputed naming of the species, I have included it here as it may be the same species as Navicula fonticula.
Navicula minnewaukonensis	S. Great Lakes(11).	G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	
Navicula navicularis	No species information found.	G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	
Navicula subminiscula	S. Present in Illinois(10). S. Present in Montana(12).	G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	
Navicula vaucheriae	S. Present in Illinois(10). S. Great Lakes(11).	G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	
Navicula ventosa	S. Present in Illinois(10).	G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	
Navicula trybionella	No species information found.	G. Extremely common, hardly a sample can be taken of epipelon without encountering this genus(1).	
Nitzschia adapta	S. Present in Illinois(10). S. Great Lakes(11).	G. Fresh to marine - usually epipelic or planktonic(1).	
Nitzschia attenuata	No species information found.	G. Fresh to marine - usually epipelic or planktonic(1).	
Nitzschia gandersheimiensis	S. Present in Illinois(10). S. Great Lakes(11).S. Present in Montana(12).	S. In the River Ter, a highly human impacted river in N.E. Spain, this species is considered quite pollutant tolerant (19). G. Fresh to marine - usually epipelic or planktonic(1).	
Nitzschia halophila	No species information found.	G. Fresh to marine - usually epipelic or planktonic(1).	
Nitzschia hungarica	S. Present in Cottonwood Study Area, Stutsman Co., No. Dakota (James River Watershed)(7). S. Present in Illinois(6, 10). S. Great Lakes(11). S. Present in Montana(12).	G. Fresh to marine - usually epipelic or planktonic(1).	

Table 9. Continued.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Stephanodiscus dubius	S. present in West Germany(49), England(20), and South Africa(50). S. Great Lakes(11). S. Present in Montana(12).	G. Freshwater to rivers, lakes and reservoirs(1). Confined to lakes and not found in marine or brackish samples (not halaphilic), also inhibited by waters of high alkalinity. S. Fresh to marine - usually epipelic or planktonic(20).	Generally now accepted as *Cyclostephanos dubius*(Mueller). *Cyclostephanos dubius* is inhabited by waters of high alkalinity(20).
Stephanodiscus rotula	S. Great Lakes(11).	G. Freshwater to rivers, lakes and reservoirs(1).	
Stephanodiscus tenuis	S. Great Lakes(11). S. Present in Montana(12).	G. Freshwater to rivers, lakes and reservoirs(1).	
Surirella fastuosa	S. Present in Brazilian coastal areas(22). S. Present in the Chesapeake Bay(21).	G. Fresh to salt water - epipelic(1).	Vinyard refers to a *Surirella fatuosa* var. *Recedens*(a marine species)(9).
Surirella peisonis	S. Great Lakes(11).	G. Fresh to salt water - epipelic(1).	
Surirella robusta	S. Present in Illinois(6, 10). S. Great Lakes(11). S. Present in Montana(12).	S. Freshwater species(9). G. Fresh to salt water – epipelic(1).	
Surirella striatula	S. Great Lakes(11). S. Present in Montana(12).	G. Fresh to salt water - epipelic(1).	
Synedra montana	S. Great Lakes(11). S. Present in Montana(12).	G. Freshwater(1).	
Synedra tabulata	S. Entire continental U.S.(4). S. Present in Illinois(10).S. Great Lakes(11).	S. In water of high conductiviity, sometimes slightly brackish(4). G. Freshwater(1). Benefits from cold fall and spring waters(45).	Listed in Patrick and Reimer under Synedra fasciculata(4).
Euglenophyta - euglenoids			
Euglena deses	S. Mich. Wisc.(3) S. Present in Illinois(6).	S. In shallow water of Sphagnum bogs and in organic detritis at margins of pools and ponds(3). G. common to waters rich in organic matter, I.e. pools, barnyards, appearing in abundance to turn waters a deep green(2).	
Euglena polymorpha	S. Wisc.(3)	S. In roadside ditches. G. common to waters rich in organic matter, I.e. pools, barnyards, appearing in abundance to turn waters a deep green(2).	
Euglena viridis	S. Present in Illinois(6).	G. Common to waters rich in organic matter, i.e. pools, barnyards, appearing in abundance to turn waters a deep green(2).	
Eutreptia viridis	S. Recorded from widely separated stations throughout U.S.(2). Recorded in the Rhode River and Chesapeake Bay(46).	S. Temp. range - 6.15 to 31.58C, salinity range 0 to 13.0ppt. Collected March, May to Sept. and Nov. from all Rhode River stations(46).	
Phacus pyrum	S. Mich. Wisc.(3). S. Present in Illinois(6).	S. Euplanktonic and tychoplanktonic(3). G. Found in a wide variety of habitats, but rarely in abundance. 32 species recorded in U.S(2).	

Table 9. Continued.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Trachelomonas horrida	S. Wisc.(3). Present in Venezuela(47).	S. Uncommon, in several swamps, ponds and ditches(3). G. Found intermingled among other algae in shallow water of ditches and bogs, or among aquatic weed beds near the shores of lakes(8).	
Cryptophyta			
Chroomonas sp.	G. multiple *Choomonas* sp. present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). G. Several species found east of the Mississippi(2).	No genus information found.	
Cryptochrysis commutata	S. found in Massachusetts(2).	No species information found.	
Cryptomonas curvata	S. Present in Drawa National Park, Poland. (24). G. Widespread(2).	No species information found.	
Cryptophyta sp.	No genus information found.	No genus information found.	
Rhodomonas rubra	No species information found.	No species information found.	
Chlorophyta - green algae			
Ankyra judayi	G. 20 species in U.S.(2). S. A planktonic algae located in Lake Erie(25).	No species information found.	
Characium sp.	G. Tiffany & Britton list 3 species in Illinois(6).	No genus information found.	
Chlamydomonas pulvisculus	G. 30 species identified in U.S.(2). No species information found.	No species information found.	G. 507 species identified although these may not all be distinct(8).
Chlorella vulgaris	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). S. Present in Illinois(6). S. Mich.Wisc(3).	S. In small lakes and pools, especially in concentration of organic matter(3). G. May be free living or grow within the cells and tissues of invertibrates.(2).	
Chlorococcum sp.	G. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). G. *C. humicola* present in Illinois(6). G. *C. humicola* is probably the most widely distributed algal species in the world(8).	G. A subaerial alga that sometimes occurs in abudance on damp soil or brickwork. Both aquatic and soil species exist(2). G. Old, wet bones and rocks under dripping water are favorable places for *Chlorococcum*(8).	
Chlorogonium sp.	G. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7).	G. Usually found in swamps and shallow ponds(8).	
Choricystis minor	S. Dominates the phytoplankton of Lake Orta, Italy(40).	No species information found.	Formerly *Coccomyxa minor* (40).

Table 9. Continued.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Cladophora crispata	S. Present in Illinois(6).	G. One of the largest genera found in fresh, brackish and salt waters. Often found at edges of streams, lakes and watering troughs(2). G. Perhaps the most characteristic habitat of *Cladophora* is on rocks in flowing water, especially on dams and waterfalls(8).	
Cladophora fracta	S. Mich., Wisc(3).	S. Floating, extremely variable species (3). G. One of the largest genera found in fresh, brackish and salt waters. Often found at edges of streams, lakes and watering troughs (2). S. A significant shading species of Michigan Lakes that restricts diversity of deeper water species (26).	
Closterium acutum	S. Present in Illinois(6).	No species information found.	
Closterium pronum	S. Rare in Central Amazon basin(28). S. Present in Chesapeake Bay(21).	No species information found.	
Coccomonas sp.	No genus information found.	No genus information found.	
Coccomyxa sp.	A widely distributed genus, circumnavigates the planet (29).	G. May grow as a free living aerial alga, as an epiphyte on lichens or as an endophyte within lichens(2). G. *Coccomyxa dispar* was the only species reported in U.S. by 1964. Forms gelatinous masses on damp soil, wet wood, old fungal sprophores; rarely free floating(8).	
Coenochloris pyrenoidosa	Reported in Czechoslovakia, Prague, Brevnov, fishpond near St. Marketa monastery (30). Present in the Lochs of Scotland(52).	G. May grow as a free living aerial alga, as an epiphyte on lichens or as an endophyte within lichens. S. Late summer and early spring species of intermittently stratifying, eutrophic Coldingham Loch, UK(52).	
Coenochloris sp.	No genus information found.	No genus information found.	
Dunaliella sp.	G. Present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7). G. worldwide(2).	G. Invariably present in salterns and brine lakes(2). G. Widely distributed and reported from all different parts of the world, occurring in brackish or saline waters(8).	
Dunaliella viridus	G. worldwide(2).	G. Invariably present in salterns and brine lakes(2). Obligate halophile(51).	
Dysmorphococcus sp.	G. *D. variabilis* found in Maryland. G. Common genus found in North America, Africa and Australia(29)	G. Grows best at a pH of 8.5 with temperatures ranging from 30-35 degrees C. Requires Ca, N, phosphate, sulfate and B-12 for growth (31).	
Elakatothrix gelatinosa	S. Wisc., Mich.(3).	S. Rare to common in various types of lakes: mostly euplanktonic(3). G. Both planktonic and non-planktonic(2). Present in Greece(32).	
Elakatothrix viridis	S. Wisc.Mich.(3). S. Present in Greece(34).	S. Rare(3). G. Both planktonic and non-planktonic(2). Present in Poland(33).	

Table 9. Continued.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Enteromorpha intestinalis	S. Found in Southeast England(35).	G. Primarily a marine alga, but becomes adapted rather easily to fresh-water habitats. Always attached to submerged plant stems, or to stones, especially in flowing water. One species is common in the far western part of the United States where it often occurs in troublesome abundance in irrigation ditches (species not named)(8). *Enteromorpha intestinalis* grows on gravel and rock bottoms. At low tide, a part of them tend to bend and float on the surface. It is quite common in rock pools, especially those that have a high position, 5 to 10 m above sea level, and get splashed during storms (36).	
Enteromorpha prolifera	S. Found in marine environments along the coast in Central California(37). It is common all around the coast of the British Isles, Scandinavia south to the Atlantic coast of Spain and Portugal, Baltic Sea. Pacific coast of America from Alaska to Mexico and Peru. Atlantic coast of America from the Canadian Arctic south to the Caribbean and Brazil. Southern Australia, Sri Lanka, and Japan (36).	S. Found in fresh and saltwater lakes(2). G. Primarily a marine alga, but becomes adapted rather easily to fresh-water habitats. Always attached to submerged plant stems , or to stones, especially in flowing water. One species is common in the far western part of the United States where it often occurs in troublesome abundance in irrigation ditches(species not named)(8). S. *Enteromorpha prolifera* is most commonly found on gently sloping shores on sheltered coasts. They are epilithic or epiphytics throughout the littoral region, extending into muddy estuaries and brackish water. It often forms tangled carpets on muddy substrates. It grows on rocks, shells, and other solid objects in rather sheltered situations at the lowest littoral level. It has alsobeen found free-floating. (36)	
Gloecoccus sp.	No genus information found.	No genus information found.	
Gloeocystis major	S. Wisc.(3). All species very common(8).	S. Tychoplankter, in hard water lakes(3). G. Both aquatic and terrestrial(2) Free floating(8)	
Gongrosira sp.	G. Wisc., Mich.(3).	G. Grows on shells of mullosks, stone and wood(3) Grow on shells and sumerged wood or aquatic plants (8).	
Kentrosphaeria sp.	G. K. gloeophila, Wisc.(3). G. *K. facciolae* present in Illinois(6).	G. *K. gloeophila*, among thick clots of blue green algae(3). G. Free living habit, usually occurring on damp soil(8).	
Keratococcus sp.	No genus information found.	No genus information found.	
Kirchneriella contorta	S. Mich., Wisc.(3).	S. Rare: in plankton of several lakes(3). G. Occurs in open water plankton(8).	
Kirchneriella elongata	S. Mich., Wisc.(3).	S. Rare: in plankton of several lakes(3). G. Occurs in open water plankton(8).	
Kirchneriella subsolitaria	S. Wisc. (3).	S. Euplankter. G. Occurs in open water plankton(8).	

Table 9. Continued.

Species Name	Geographic distribution (S.=species, G.=genus)	Habitat (S.=species, G.=genus)	Taxonomy notes for PBOC algae species (S.=species, G.=genus)
Monoraphidium mirabile	No English Language Citations found.	No English Language Citations found.	
Nannochloris sp.	G. Found in a variety of inland brackish conditions in western Europe(38).	G. Found in generally brackish inland waters (38).	
Oocystis crassa	S. Wisc. Mich.(3). S. Present in Illinois(6).	S. Rare in plankton of Wisconsin and Michigan(3). G. frequent in the plankton of lakes and in the microflora of pools and ditches(2).	
Oocystis gloecystiformis	S. Wisc.(3).	S. Among other algae in a few soft water lakes and swamps(3). G. Frequent in the plankton of lakes and in the microflora of pools and ditches(2)	
Oocystis pyriformis	S. Wisc(3).	S. Found in Cedar Swamp in Wisconsin(3). G. Frequent in the plankton of lakes and in the microflora of pools and ditches (2).	
Oocystis submarina	S. Wisc. Mich.(3).	S. In eu- and tychoplankton(3). G. Frequent in the plankton of lakes and in the microflora of pools and ditches(2).	
Pediastrum sp.	S. *P. boryanum* and *P. tetras* present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). G. Many species present in Wisconsin and Michigan(3).	G. Often encountered in collections from permanent or semi-permanent pools(2).	
Polytoma uvella	S. Reported from several parts of the United States(2).	No species information found.	
Pseudosphaerocystis lacustris	Present in Lake Vattern, Sweden(41).	S. Found in Lake Vattern, an oligotrophic lake with minimal levels of salinity and large freshwater inputs (41).	
Pseudoulvella sp.	G. *P.americana* is found in Michigan and Iowa(2). *P. americana* found in Mich. and Wisc(3).	G. *P. americana* grows on the culms of *Scirpus*, on submerged wood etc.(3).	*Psuedulvella* is the name referred to in all texts where present.
Scenedesmus bicaudatus	S. Found in Ho Tay Lake, Hanoi City, Viet Nam(41). S. Found in the Amazon Basin(39).	S. High Mountain and foothills in Amazon Region(39).	
Scenedesmus granulatus	S. Found in the Amazon Basin(39).	S. Low areas in Amazon Region(39).	
Scenedesmus linearis	S. Found in the Amazon Basin(39). S. Present in the Phytoplankton of the Gulf of Gdansk, Baltic Sea (27).	S. High Mountain areas of the Amazon Region(39).	
Scenedesmus opoliensis	S. Mich and Wisc,(3). S. Present in Illinois(6). S. Found in the Amazon Basin(39).	S. Rare, but widely distributed(3). S. Foothills and lowlands of the Amazon Region (39).	
Scenedesmus subspicatus	No species information found.	No species information found.	
Schroederia judayi	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota (James River Watershed)(7). S. Mich and Wisc,(3)	S. Rare, in euplankton(3).	

Table 9. Continued.

Species Name	**Geographic distribution (S.=species, G.=genus)**	**Habitat (S.=species, G.=genus)**	**Taxonomy notes for PBOC algae species (S.=species, G.=genus)**
Selanastrum capricornutum	G. Widely distributed throughout the country(2)	G. Found as free floating algae in pools and other quiet waters(2).	
Stephanoptera gracillis	S. Present in Cottonwood Study Area, Stutsman Co. No. Dakota(James River Watershed)(7). S. Found in several saltern and brine lakes in the western United States(2).	S. Found in several saltern and brine lakes in the western United States(2). Motile(8).	
Stichococcus sp.	G. Recorded from numerous localities around the country(2). G. Wisc. and Mich.(3). G. Illinois (6).	G. Grows on damp soil(2). G. In algal mixtures encrusting submerged wood, or on aquatic plants(3). G. Most species found on the bark of trees, old boards, or damp soil(8).	
Stigeoclonium attenuatum	S. Mich and Wisc,(3).	S. In Wisconsin and Michigan bogs, attached to submerged aquatics(3). G. A late spring and autumn algae. S. Grows in slowly flowing clear-water brooks, springs and the overflow from fountains and water troughs (2).	
Tetraselmis cordiformis	S. collected at a ditch at Munster Castle, Germany(38). Abundant in German "alkenone" lakes(34).	S. Freshwater in ditches and "alkenone" lakes(34).	
Ulothrix acqualis	S. Mich and Wisc,(3).	S. Common: forming pure, bright green masses in shallow water of several lakes and swamps: scattered among other algae(3). G. Usually found in quiet or running water. Also, cliffs moistened by waterfall spray(2).	

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Table 10. Rotifera PBOC characteristics used in selection/deselection decisions. All species listed have been observed in Devils Lake.

NAME	DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON PBOC ROTIFER SPECIES
Asplancha sp**.**	Present in prairie pothole region (1) and Great Lakes Region. Widely dispersed (2), (3) (see background on rotifers)	Limnetic. One of most abundant open water plankton (4). Confined to alkaline waters >7 ph (4). Omnivorous genus known to eat large algae and rotifers.	none
Asplancha silvestris	unknown	see *Asplancha* sp.	none
Atrochus tentaculatus	Also reported in Europe (5).	see *Asplancha* sp.	none
Brachionus sp**.**	Genus is cosmopolitan (7). Present in prairie pothole region (1). Reported in Red River in low abundance (6).	Often occurs in the littoral zone. Occurs also in limnetic zone especially in algal blooms or eutrophic areas (5). Very common in open water plankton (4). Confined to alkaline waters >7 ph (4).	none
Brachionus calyciflorus pala	Cosmopolitan (5)(7). Widely dispersed, present in Great Lakes Region (2),(3).	Eutrophic indicator species (2). Planktonic, tolerates gross pollution (5).	*B. pala = B. calyciflorus*
Brachionus capsuliflorus quadridentatus	Widely dispersed, present in Great Lakes Region (2), Wisconsin (8).	Known to eat blue-green algae Aphanizomenon (2)	none
Brachionus dolabratus	Also found in S. America and Europe (7).	see *Brachionus sp.*	none
Brachionus havanaensis	Widely dispersed, present in Great Lakes Region (2),(3), S. America, Australia (7).	see *Brachionus sp.*	none
Brachionus plicatilis	Cosmopolitan (7).	Does not tolerate freshwater well, prefers saltwater (7).	none
Brachionus plicatilis spatiosus	unknown	see *Brachionus sp.*	none
Brachionus pterodinoides	In S. America, N. America and Europe (7).	see *Brachionus sp.*	none
Brachionus urceolaris	Cosmopolitan (5)(7). Present in Great Lakes Region (2),(3).	Littoral, but may move into open water in polluted waters (5).	none

Table 10. Continued.

NAME	DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON PBOC ROTIFER SPECIES
Brachionus satanicus	unknown	unknown	none
Cephalodella catellina	Cosmopolitan (5).	In fresh to brackish water, occasionally found in coastal marine environment (2). Found amongst aquatic plants (5).	There are over 100 species of Cephalodella (4).
Cephalodella megalocephala	Cosmopolitan (2).	In mudflats, beaches, sand, periphyton of freswhater margins (2).	none
Cephalodella stera	Cosmopolitan (2).	Cosmopolitan in sediment, rivers (2).	none
Colletheca cornuta	Widely dispersed, present in Great Lakes Region (2).	Most Coletheca are littoral species, many are predatory (4).	none
Colurella adriatica	Found in U.S. and Europe (5).	Littoral zone of lakes, ponds and rivers (5).	none
Colurella colurus	Cosmopolitan (5).	Littoral zone (5).	none
Filinia longiseta	Cosmopolitan (5), occurs in Great Lakes Region (2). One of most abundant open-water plankton species (4).	Confined to alkaline waters >7 ph (4). Warm stenotherm, summer season,eat bacteria. Not abundant in rivers (6).	none
Hexarthra sp.	Widely dispersed (2).	*H. mira* reported in Great Lakes (2).	none
Hexarthra fennica	unknown	unknown	none
Keratella cochlearis	Cosmopolitan (7), present in Great Lakes Region (2). One of most abundant open-water plankton species (4).	Most common freshwater rotifer genus and *K. cochlearis* is most abundant species(1),(3). Generalist feeder--eats detritus, bacteria and cryptomonads and chrysomonads (2)(4).	none
Keratella quadrata	Cosmopolitan (7), present in Canada and prairie pothole region (1).	Eurythermous , may be present in plankton throughout the year. Known to be eaten by *Daphnia sp., Hesperodiaptomus arcticus* (4).	none

Table 10. Continued.

NAME	DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON PBOC ROTIFER SPECIES
Lecane bulla	Cosmopolitan (5), present in Great Lakes Region (2), present in prairie pothole region (1).	Common, occurs in limnetic and littoral zone (5).	Formerly listed in *Monostyla* genus.
Lecane cornuta	Widely dispersed, presumably cosmopolitan, present in prairie pothole region (1) and Great Lakes (2).	unknown	Formerly listed in *Monostyla* genus.
Lecane inermis	Cosmopolitan (5).	Common eurytopic (fresh, saline and marine areas) in littoral zone (5).	none
Lecane luna	Common species, present in Great Lakes Region (2).	unknown	none
Lecane lunaris	Cosmopolitan (5), present in Great Lakes Region (2).	Most common cosmopolitan littoral species (5). Eurytropic species. Most common Lecane species in Great Lakes (2).	none
Lecane quadridentata	Cosmopolitan, present in Great Lakes Region (2), present in prairie pothole region (1).	Eurytropic, relatively common.	Formerly listed in *Monostyla* genus.
Lecane sp.	Genus is cosmopolitan. Present in prairie pothole region (1).	Common in shallow, littoral zone also in limnetic zone of eutrophic river mouths and harbors (2)(4).	Many small species.
Lepadella patella	Widely dispersed, present in Great Lakes Region (2).	Littoral species generally (2).	none
Lepadella sp.	Widely dispersed, present in Great Lakes Region (2).	Occurs in littoral zone (4).	Very small species.
Mytilina ventralis brevispina	Widely dispersed, present in Great Lakes Region (2).	Reported in littoral areas.	none
Notholca acuminata	Widely dispersed, present in prairie pothole region (1) and Great Lakes (2). Found in Red River water quality samples in low abundance (6).	Cold stenothermic, common at inshore areas during winter and spring. Confined to alkaline waters >7 ph (4). Stenophagus, feeding on small centric diatoms.	none
Notholca striata	Widely dispersed, present in Great Lakes Region (2), Wisconsin (8).	Cold stenothermic. Confined to alkaline waters >7 ph (4).	none
Notommatta sp.	Widely dispersed, present in Great Lakes Region (2).	Reported in littoral areas (4)	none

Table 10. Continued.

NAME	DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON PBOC ROTIFER SPECIES
Philodina sp.	Widely dispersed, present in Great Lakes Region (2).	Benthic genus that is very common. Common in sewage treatment process.	A Bdelloid rotifer. Little known genus (2).
Platyias quadricornis	Widely dispersed, present in Great Lakes Region (2) and prairie pothole region (3).	Uncommon in littoral areas, most common in summer. Presence in limnetic zone may indicate eutrophism.	none
Ptygura sp.	Widely dispersed, present in Great Lakes Region (2).	A sessile rotifer genus (9).	There are *Ptygura* 20 species (4)
Squatinella mutica	Uncommon but widely dispersed, present in Great Lakes Region (2).	unknown	Formerly known as *Stephanops muticus*
Testudinella patina	Widely dispersed, present in Great Lakes Region (2), reported in Wisconsin (8).	Uncommon genus, reported in littoral areas (2).	none
Trichocerca sp.	Widely dispersed, present in prairie pothole region (1) and Great Lakes (2). Was found in Red River water quality samples in low abundance (6).	Littoral and limnetic zones (2). Associated with oligotrophic (low productivity and nutrient level) water. (5)	Large genus (4), containing many species

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Table 11. Crustacea (Cladocera and Copepoda) PBOC characteristics used in selection/deselection decisions. All listed species have been reported in Devils Lake.

TAXON	**GEOGRAPHIC DISTRIBUTION**	**HABITAT**	**TAXONOMIC NOTES ON CANDIDATE PBOC ZOOPLANKTON CRUSTACEA**
Cladocera			
Alona rectangula	North America and Eurasia.	Found to prefer subsaline to hyposaline lakes in their lower range in Europe (1) In Aral Sea occurred only in in waters > 8 0/00 salinity (2)	none
Bosmina longirostris	Widespread and common (3) if not cosmopolitan. Present in Lake Winnipeg 1997 (4).	Occurs in limnetic zone (3). In Aral Sea occurred only in in waters < 8 0/00 salinity (2).	none
Ceriodaphnia pulchella	Also occurs in Eurasia. Reported occurrences in Ontario lakes	Occurs in limnetic zone, In Aral Sea occurred only in in waters < 8 0/00 salinity (2).	none
Ceriodaphnia quadrangula	Also occurs in Eurasia. Present in Lake Winnipeg 1997 (4).	In Aral Sea occurred only in in waters > 8 0/00 salinity (2).	none
Chydorus sphaericus	Cosmopolitan (3). Most widespread Cladocera spp. in world (5), Present in Lake Winnipeg 1969 (4).	In Aral Sea occurred only in in waters < 8 0/00 salinity (2).	none
Daphnia spp.	Widespread genus (3). Often a key genus in aquatic food chain (6).	Widespread	*Daphnia* species have interspecific hybridization, phenotypic plasticity and regional morphological variation (7), which creates difficulties differentiating between "species", "species-complexes" and/or "sub-species".
Daphnia galeata mendotae	Present in Lake Winnipeg 1997 (4), Ashtabula Reservoir, Sheyenne River, North Dakota (8). Widespread in temperate North America (9).	Occurs in limnetic zone. Hybridizes with other species.	none

Table 11. Continued.

TAXON	GEOGRAPHIC DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON CANDIDATE PBOC ZOOPLANKTON CRUSTACEA
Daphnia longiremis	Broadly distributed in northern North America (8).Present in Lake Winnipeg 1969 (4)	Cold stenotherm (9).	none
Daphnia longispina	Cosmopolitan (3),(9). Present in Lake Winnipeg 1929 (4)	In Aral Sea occurred only in waters < 8 0/00 salinity (2).	none
Daphnia magna	Broadly distributed in Eurasia, but limited to western half of Nearctic zone (7). Also Western U.S., Mexico to Arctic Ocean (3).	Mostly found in intermittent ponds, eutrophic, slightly saline up to 200 uS/cm. Preferred saline lakes in Spanish study. One of most widely studied *Daphnia spp*. Superior competitor when food is abundant to other *D. pulex* and longispina (10). Use of macrophytes and clonal ecology see (11)(12).	none
Daphnia pulex	Also occurs in Eurasia, possibly cosmopolitan. Present in Lake Winnipeg 1997 (4). Very abundant in Lake Ashtabula, North Dakota (8). Characteristic of non-glacial lakes (9).	Occurs in limnetic zone. This species was found to be competive in lab experiments excluding *D. longispina* (10).	none
Daphnia schoedleri	Present in Lake Winnipeg 1997, (4) and Ontario (13).	Occurs in limnetic zone.	none
Daphnia similis	Found in North America in western saline lakes (3)(7). Distribution matches *Diaptomus nevadensis*. Broadly distributed in Eurasia, but limited to western half of Nearctic zone (7).	Usually in temporary, saline, or alkaline ponds (3). A western species, with broad salinity tolerance, but prefers higher salinity. In some situations it is abundant in eutrophic waters.	*D. psittacea* is same species. Consists of a complex of species with similar traits (7).
Diaphanosoma birgei	Throughout North America- Arctic to Louisiana, N. Europe and Asia	Occurs in limnetic zone, in sheltered areas (3). Little research has been done on this species.	none
Diaphanosoma brachyurum	Cosmopolitan. Present in Lake Winnipeg 1929, (4). Also in Africa, Central and South America (	Found in littoral and pelagic areas. In Aral Sea occurred only in waters < 8 0/00 salinity (2).	none

Table 11. Continued.

TAXON	GEOGRAPHIC DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON CANDIDATE PBOC ZOOPLANKTON CRUSTACEA
Diaphanosoma leuchtenbergiannum	Present in Lake Winnipeg 1969, (4). Reported in Ontario(13)	Occurs in limnetic zone (3).	none
Moina affinis	Widespread in N. America. Found in small aestival ponds in Wisconsin (14).	Widely distributed. Found to occur in association with *Daphnia pulex* and *Ceriodaphnia affinis* (14).	none
Moina macrocopa	Also occurs in Eurasia.	Widespread, but not abundant (3). Non-selective filter feeder (15).	none
Simocephalus vetulus	Also occurs in Eurasia. Present in Lake Winnipeg 1969, (4) and in prairie pothole wetlands (Labaugh and Swenson 1988).	Leaves of aquatic vegetation (17)	none
Copepoda			
Acanthocyclops robustus	Present in Europe and North America.	Associated with Eutrophic lakes in Europe (19)(20).	*A. robustus (3)* and *A. vernails* often considered same species group. *A. robustus* is subject of much research in Europe.
Acanthocyclops vernalis	Widely distributed in North America, present in Lake Winnipeg 1997 (4).	Eutrophic shallow near-shore, water column and benthic (3). A dominant zooplankton in Danube River (21).	*A. robustus* and *A vernails* often considered same species group (3*).*
Aglaodiaptomus clavipes	Erratically distributed between Mississippi River and the Continental Divide (3).	unknown	none
Cletocampus albuquerquensis	Distribution unknown	A little-known harpacticoid copepod	none

Table 11. Continued.

TAXON	GEOGRAPHIC DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON CANDIDATE PBOC ZOOPLANKTON CRUSTACEA
Cyclops viridis americanus	*C. viridis* present in Lake Winnipeg 1929 (4*).*	See taxonomic notes	*C. viridis* was originally believed to be European. *C. viridis-americanus* is a species complex (22).
Cyclops serrulatus	Present in Lake Winnipeg 1929 (4).	See taxonomic notes.	none
Diacyclops navus	Uncommon but widely distributed in Canada (23).	Found in small lakes, ponds and pools (3), primarily in littoral zone (23).	Was thought to be sub-species of *Diacyclops bicuspidatus thomasi* until 1959 (23).
Diacyclops thomasi	Common and widely distributed in North America, present in Lake Winnipeg 1997 (4).	Cold water in lakes, ponds, rivers, open water-limnetic. Dominant in large, deep lakes.	This species was formerly called *Cyclops bicupidatus thomasi.*
Diaptomus sp.	Present in Lake Winnipeg 1969 (4).	unknown	none
Diaptomus leptopus piscinae	Occurrences reported in Great Lakes region, North Dakota, New England and Colorado (3) (24). Present in Lake Winnipeg 1969 (4).	unknown	Same species as *D. leptopus* Forbes 1893 and *D. piscinae* Forbes 1893 (24).
Diaptomus nevadensis	North America --Reported in California, Nevada, Washington, North Dakota (3)	Occurs in saline lakes, rare (3). Carnivorous species (26). *D. nevadensis* was thought to be eliminated from a lake in Washington from the introduction of *Chaoborus flavicans* (25).	This species is sometimes called *Hesperodiaptomus nevadensis*.
Diaptomus shoshone	Occurrences reported in northern US and Canada, west to California and east to Lake Ontario region (24).	unknown	none
Diaptomus sicilis	Present in Lake Winnipeg 1969 (4). Limited to Glacial North America (9). Present in Ontario. Reported in Great Lakes region, and Prairie potholes. Occurs west to Wyoming and north to Saskatchewan (24).	Occupies limnetic zone.	none
Diaptomus siciloides	Widely distributed in N. America from Indiana, south to El Salvador, west to California, US, north to N. Dakota (24). Present in Lake Winnipeg 1997 (4).	unknown	none

Table 11. Continued.

TAXON	GEOGRAPHIC DISTRIBUTION	HABITAT	TAXONOMIC NOTES ON CANDIDATE PBOC ZOOPLANKTON CRUSTACEA
Hesperodiaptomus sp.	Distribution varies by species.	Predatory calanoid copepods (26).	see *Diaptomus nevadensis*
Laophonte sp.	unknown	A little-known harpacticoid copepod (3).	none
Macrocyclops albidus	Common and widely distributed.	Common and widely distributed, especially in vegetation and on bottom (benthic) (3).	none
Mesocyclops edax	Present in Lake Winnipeg 1997 (4).	Occurs in limnetic zone.	none
Mesocyclops leuckarti	Reported from British Columbia to Quebec in Canada.	Prefers warm water (28).	Some scientists group *M. edax* and *M. leuckarti* as part of the same species complex. *M. leuckarti* was previously named *Cyclops leuckarti*.

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Table 12. Distributions in Canada of PBOC zooplankton crustaceans.

SPECIES NAME	KNOWN DISTRIBUTION	Would introduction into Lake Winnipeg, cause range expansion ?
	Subclass Cladocera (water fleas)	
Daphnia similis	Distributed widely in Eurasia, usually in temporary, saline, or alkaline ponds. Found widely in Saskatchewan, also in Alberta, B.C., Canada (Patalas, Patalas, and Salki 1994). Similar distribution to *Diaptomus nevadensis*.	Probably
Diaphanosoma birgei	Throughout North America- Arctic to Louisiana, N. Europe and Asia.	No
Moina affinis	Widespread in N. America. Reported in small aestival ponds in Wisc.	No
	Subclass Copepoda	
Acanthocyclops robustus	Cosmopolitan –Widely distributed in North America	No
Aglaodiaptomus clavipes	Erratically distributed between Mississippi River and the Continental Divide. *Diaptomus clavipes* Schacht, (possibly the same species) was found in Lake Winnipeg and elsewhere in Manitoba (Bajkov 1934)	No
Cletocampus albuquerquensis	A Harpacticoid copepod- lack of data on this family. Found in Cottonwood Lakes Area, North Dakota.	Probably
Diacyclops navus	Found in small lakes, ponds and pools. Uncommon, but widely distributed in Canada.	No
Diaptomus nevadensis	Reported in saline lakes in California, Nevada, Washington, North Dakota, and western Canada. Found widely in Saskatchewan, also in Alberta, and B.C., Canada (Patalas, Patalas, and Salki 1994).	Insufficient information
Laophonte sp.	Harpacticoid-lack of data on this family. *Laophonte calamarum* was found in Lake Winnipeg Basin (Bajkov 1934).	Insufficient information

Table 13. Toxins produced by Cyanobacteria, and their effects.

Toxin	Associated species	Effects and Public Health Concern
Neurotoxins		
Saxitoxin	*Anabaena circinalis*	Sodium channel blocking agent. Acute poisoning results in death by paralysis and respiratory failure. Toxicity only at very high cell densities.
Hepatotoxins		
Microcystin	*Microcystis aeruginosa*	Acute toxicity unlikely in large water supplies. Chronic liver damage with ongoing exposure. Tumor growth has been linked to this species although findings are not yet conclusive.
Nodularin	*Nodularia spumigena*	Acute toxicity unlikely in large water supplies. Chronic liver damage with ongoing exposure. Tumor growth has been linked to this species although findings are not yet conclusive. This species has not been found in blooms in Australian reservoirs, only estuarine lakes.
Cylindrospermopsin	*Cylindrospermopsis raciborskii*	Liver damage and gastrointestinal tract damage.
Endotoxins		
Lipopolysaccharides	Most cyanobacteria	Gastrointestinal disorders, skin and eye irritation and rashes, as well as respiratory allergy. Less toxic than hepato- or neurotoxins. Effects from chronic exposure not known. Possible significant for water supply in relation to bathing.

Source: Steffensen et al. 1999.

Table 14. A sampling of halophilic biota recorded from Devils Lake, ND, but not from the Sheyenne River, Red River, or Lake Winnipeg.

Taxon	Common names and habitat comments[1]
Artemia salina	brine shrimp; crustacean species complex of inland saline waters worldwide
Chaetoceros muelleri	diatom (algae) from primarily marine genus
Coscinodiscus lacustris (a.k.a. *Thallassiosira bramaputrae*)	diatom from marine genus
Cothurnia curva and *C. imberbi*	ciliate protozoa from primarily marine genus
Cyclotella meneghiniana	diatom found in marine habitats
Enteromorpha intestinalis & E. prolifera	green algae in primarily marine genus
Ephydra spp.	shore flies, brine flies, most common insect in saline waters
Lacrymaria lagenula	marine ciliate protozoan
Ruppia maritima	wigeongrass, halophilic vascular plant
Spirulina norstedtii & *S. subtilissima*	blue-green algae
Synechococcus sp.	blue-green algae genus found in some marine habitats
Uronema marinum	green alga found in salt water

[1] From sources cited in Tables 9 and 10.

Table 15. Devils Lake, ND algae also found in Cottonwood Lakes Area, Stutsman County, ND wetlands. Includes mean densities (#cells/ml) from $MgHCO_3$ wetlands and $NaSO_4$ wetlands.

Algal group	Genus/species	PBOC[1]	$MgHCO_3$ density	$NaSO_4$ density
Cyanophyta	*Anabaena* sp. [2]	no	354	417
"	*Aphanizomen*on sp.	no	0	587
"	*A. delicatissima*	yes	3173	5680
"	*Aphanothece* sp.	no	2779	1060
"	*Chroococcus* sp.	no	701	85
"	*Dactylococcopsis fascicularis*	yes	66	9656
"	*Gloeocapsa* sp.	yes	83	2286
"	*Lyngbya* sp.	no	1083	8804
"	*Oscillatoria* sp.	no	3578	6958
"	*O. angustissima*	no	1791	4544
"	*O. chlorina*	yes	2000	12,922
"	*O. limnetica*	no	1375	2021
"	*O. limosa*	no	0	3692
"	*Phormidium* sp.	yes	114	8864
"	*Rhabdoderma* sp.	yes	0	76
"	*Spirulina major*	yes	292	63
"	*Synechochoccus* sp.	yes	85,825	1,314,068
Cryptophyta	*Chroomonas* sp.	no	341	3342
"	*Cryptomonas* sp.	no	0	331
"	*C. erosa*	no	795	5
"	*Rhodomonas* sp.	no	417	19
Chlorophyta	*Ankistrodesmus* sp.	no	28	38
"	*Chlamydomonas* sp.	no	497	947
"	*Chlorella* sp.	yes	0	76
"	*C. vulgaris*	yes	19	14
"	*Chlorogonium* sp.	yes	57	530
"	*Dunaliella* sp.	yes	0	57
"	*Gloeocystis* sp.	no	0	47
"	*Oocystis* sp.	no	0	284
"	*Pyramimonas* sp.	no	0	7
"	*Scenedesmus* sp.	no	42	38
"	*Selenastrum* sp.	no	0	9
"	*Spermatozoopsis* sp.	yes	0	5
"	*Stephanoptera gracilis*	yes	0	19
Euglenophyta	*Euglena* sp.	no	38	189
Chrysophyta	*Chromulina* sp.	no	38	71
"	*Ochromonas* sp.	no	95	2414

Table 15. Continued.

Algal group	Genus/species	PBOC[1]	$MgHCO_3$ density	$NaSO_4$ density
Bacillariophyta	*Cyclotella meneghiniana*	no	28	1041
"	*Eunotia curvata*	no	0	19
"	*Gomphonema* sp.	no	9	5
"	*G. gracile*	no	0	9
"	*G. parvulum*	no	0	19
"	*Navicula* sp.	no	19	19
"	*N. capitata*	no	0	9
"	*N. cincta*	no	0	805
"	*N. cryptocephala*	no	5	47
"	*N. cryptocephala var. veneta*	no	67	214
"	*N. heufleri*	no	21	1319
"	*N. lanceolata*	no	21	63
"	*N. minscule*	yes	19	9
"	*N. tripunctata*	no	30	205
"	*Nitzschia* sp.	no	229	180
"	*N. fonticola*	no	0	2
"	*N. frustulum*	no	0	26
"	*N. hantzshiana*	no	31	128
"	*N. inconspicua*	no	0	323
"	*N. linearis*	no	19	85
"	*N. palea*	no	65	183
"	*N. paleacea*	no	305	453
"	*Pinnularia* sp.	no	5	284
"	*Rhoicosphenia curvata*	no	0	158
"	*Rhopalodia gibba*	no	24	47
"	*Synedra fasciculata*	no	0	151

[1] Potential Biota Of Concern = recorded from Devils lake, but not from remainder of Red River of the North or Lake Winnipeg basins.

[2] "sp." indicates specimens not identified to species level by LaBaugh and Swanson (1988). These specimens may not include species that occur in Devils Lake.

Table 16. Summarized project results: screening of all Devils Lake taxa and automatically-listed taxa (ALT) from Candidate PBOC through BRA stages, with recommendations for further action.

BIOTA GROUP	# of Candidate PBOC Taxa	# of 1st-Round Deselections	1st-Round Deselection Reasons[1]	# of PBOC (w/ALT)	# of 2nd-Round Deselections	2nd-Round Deselection Reasons	Results: further analysis of remaining species	# of BRA taxa	Recommendations
Algae	526	310	All deselected taxa: A	**216 (0)**	212	B, D (& probably A)	4 species: hazard probability very low	**0**	Monitor concentrations of nutrients, salts, & toxic Cyanobacteria in outlet
Vascular Plants	368	353	All deselected taxa: A	**15 (15)**	15	4 ALT: A 11 ALT: C	None	**0**	Consider monitoring for "reverse" transfers FROM Red River basin TO Devils Lake
Protozoa	94	0	n.a.	**94 (0)**	94	B, D (& probably A)	None	**0**	None
Invertebrates	161	88	All 52 insect and mite taxa: B 36 other taxa: A	**69 (4)**	69	4 ALT: C All others: B, D (& probably A)	None, but see Recommendations	**0**	Initial survey, future monitoring for zebra mussel, rusty crayfish, spiny water flea in Devils Lake
Fishes	27	11	All deselected taxa: A	**16 (16)**	14	C	None, but see Recommendations	**0**	Future monitoring for zander, grass carp in Devils Lake
Fish Parasites	8	5	All deselected taxa: A	**3 (0)**	0	n.a.	3 species: already found in Red River basin	**0**	Find Acanthocephalan worms in Devils Lake fishes and obtain authoritative identification
Fish Pathogens	7	0	n.a.	**7 (7)**	7	C	n.a.	**0**	Screen Devils Lake basin fishes for pathogens
Other Pathogens	1	0	n.a.	**1 (0)**	1	B	n.a.	**0**	None

[1]Deselection Codes: A - known/believed to be already present in Red River basin; B - existing interbasin transfer pathways believed to be very effective; C - not known to exist in Devils Lake basin; D - not known to cause problems; believed to be benign

APPENDIX

EXPERTS CONSULTED

US Geological Survey
Robert Goldstein, Northern Prairie Wildlife Research Center - Red River biota

Fisheries and Oceans Canada
Mr. Dennis Wright, Freshwater Institute - Manitoba fishes and Lake Winnipeg studies
Dr. Alex Salki, Freshwater Institute - plankton of Lake Winnipeg and Canada

Manitoba Conservation
Mr. Walt Lysack, Fisheries Branch, Sport and Commercial Fishing – Lake Winnipeg fishery
Ms. Shirley Romano – industrial and commercial water usage

Minnesota Department of Natural Resources
Mr. Joe Marcino, Fish Pathology Laboratory - Minnesota fish parasites
Mr. Paul Stolen, Region 1 Environmental Assessment Ecologist, Bemidji office - biota transfer
Mr. Chip Welling, Invasive Species Specialist – Eurasian watermilfoil control methods

North Dakota Department of Fish and Game
Mr. Randy Hiltner, Eastern District Fisheries Biologist - Devils Lake fishery
Mr. Terry Steinwand, Fisheries Division Chief - North Dakota fishes and biota transfer
Mr. Jerry Weigel, Fisheries Production and Development Section - North Dakota fish pathology

North Dakota State Health Department
Dr. Karen Phillips, North Dakota Health Department - Sheyenne River and Devils Lake algae

North Dakota State Herbarium
Dr. William Barker, Curator - North Dakota flora
Dr. Shawn DeKeyser, Research Technician - North Dakota flora

North Dakota State University
Dr. Marvin Fawley, North Dakota State University - Sheyenne River and Devils Lake algae
Dr. John Peterka, Emeritus, North Dakota State University - fishes and Devils Lake biota

University of Manitoba
Dr. Terry Dick - fish parasites

University of North Dakota
Dr. Harry Holloway, Emeritus, University of North Dakota - fish parasites

Valley City State University
Dr. Bonnie Alexander, Valley City State University - Eurasian watermilfoil
Dr. Andre DeLorme, Valley City State University - Sheyenne River macroinvertebrates

Wisconsin Department of Natural Resources
Ms. Sue Marcquenski, Bureau of Fisheries Management - *Heterosporis* disease in fishes

Other
Mr. Kelly Bakken, Ed's Bar, Bait, and Convenience - bait sources

Vascular Plant Resources: Print Sources and Expert Consultations

Source: Northern Great Plains Floristic Quality Assessment Panel. 2001. Floristic Quality Assessment for North Dakota, South Dakota (excluding the Black Hills) and Adjacent Grasslands. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resources/2001/fqa/fqa.htm (Version 26JAN2001)

This document was prepared based on a conference held at the North Dakota State Herbarium at NDSU. It included as an appendix, a complete and up to date listing of 1,564 vascular plant species found in both states (personal communication with W.T. Barker, Curator ND Herbarium). Each species is listed with a set of attributes, including location collected and state presence. The list was acquired in text format, imported to Excel and sorted to exclude species not occurring in North Dakota. A current list of North Dakota vascular plants was thus developed.

Source: 1996 National List of Vascular Plant Species That Occur in Wetlands. http://wetlands.fws.gov/bha.

The Fish and Wildlife Service has prepared a National List of Vascular Plant Species That Occur in Wetlands: 1996 National Summary (1996 National List). The 1996 National List is a draft revision of the National List of Plant Species That Occur in Wetlands: 1988 National Summary (Reed 1988). The 1996 National List reflects a significant amount of new information that has become available since 1988 on the wetland affinity of vascular plants. This new information has resulted from the extensive use of the 1988 National List in the field by individuals involved in wetland and other resource inventories, wetland identification and delineation, and wetland research.   This list was acquired in ASCII format, imported into Excel and sorted to select only species and their wetlands ratings for the Northern Plains Region. The resulting list was then sort by indicator status. Species listed as FACW to OBL were selected and all others deleted.

The total list of plants found in North Dakota was electronically compared with the FACW/OBL Northern Plains Species list. All matching North Dakota Species were retained and this list was screened against three other primary sources and several additional sources to develop lists of species occurring only at Devils Lake or only in the Red River Basin.

Source: Two draft reports under preparation by Dr. William Barker, Curator of the North Dakota State Herbarium (NDSH) and Dr Shawn DeKeyser, Research Technician NDSH: The Vascular Plants of Camp Grafton (North Unit) and The Vascular Plants of Camp Grafton (South Unit).

These documents are scheduled for completion in 2001 (personal communication with W.T. Barker, 9/5/2001). Each contains an annotated appendix of all species found during a two-year study (which is follow-up study to the 1996 thesis prepared by Dr. S. DeKeyser). Camp Gilbert C. Grafton is located on a peninsula jutting into the approximate geographic center of Devils Lake. The collection included shoreline, emergent, floating and rooted aquatic species occurring in both Main Bay and the somewhat more saline, East Bay. The annotated appendices contain 218 species, several of which were new findings for North Dakota. It was necessary to add several species to the list developed from the first comparison.

Source: Two site visits conducted by the author during the 2001 growing season.

The first was a five-day driving tour of the Red River Basin conducted June 24 through June 28. The main stem of the Red River, from Breckenridge to Pembina, and mast of the major tributary streams were visited. There were 179 wetland and aquatic species were recorded with the basin. The second visit, conducted from September 6 through September 9, was at Devils Lake only. A driving tour circumnavigated the lake. Portions of the lake were explored along the fringes in a small boat. Eleven locations, about an acre in area, were sampled around the lake perimeter and all species recorded. There were 60 wetland or aquatic species noted during this survey.

Source: Barker, W.T. and T. Mitchell. 1977. Atlas of the Flora of the Great Plains. The Great Plains Flora Association. The Iowa State University Press. Ames, IA.

This is the seminal work of plant geography for the Great Plains. It includes: 1) a county by county map for every population of vascular plant species known at the time of printing (including species within the prairie portion of Minnesota) and, 2) a list of infrequent taxa, found once or only occasionally. This resource was used to screen the Northern Plains FACW/OBL list and to identify counties along the Red River and Devils Lake, within which a species is mapped.

A species was considered to be in the Devils Lake Basin if mapped in Ramsey or Benson Counties. Almost all of Ramsey County is occupied by Devils Lake or is within its drainage basin, exclusive of the Red or Sheyenne River Basins. The northern one-third of Benson County drains to Devils Lake. A species mapped here was presumed to occur in either or both the Devils Lake and Sheyenne River Basins.

Cross-referencing the lists from the above sources resulted in 15 species reported from the Devils Lake basin but not from the Red River basin. Then the last source was consulted:

Source: USGS. 1999. Aquatic and Wetland Vascular Plants of the Northern Great Plains. Northern Prairie Wildlife Research Center. http://www.nprwrc.usgs.gov/resource/1999/vascplnt/species

Larson, Gary E. 1993. *Aquatic and wetland vascular plants of the Northern Great Plains*. Ft. Collins, U.S. Dept. of Agriculture, Forest Service, Rocky Mountain and Range Experiment Station. USDA Forest Service, General Technical Report RM-238, 681 p.

The source document is the most up to date compilation of plant geography and includes the work of Gary Larson while at NDSU and the findings of subsequent NDSU graduates, USGS researchers and other contributing botanists. The document maps species distribution by county, like Atlas of the Flora of the Great Plains, but apparently includes only the species for which there are more recent population distribution findings.

All 15 species emerging from the second comparison are included in this source. All are shown to occur in both the Devils Lake Basin (Ramsey and Benson Counties) and also in the Red River Basin counties of North Dakota and/or Minnesota.

Algae and Invertebrate Resources: Expert Consultations

Summary of consultation with Dr. Bonnie Alexander, VCSU

July 21, 2001.

Via e-mail, Dr. Alexander confirmed reports of Eurasian watermilfoil occurring in the Sheyenne River.

She was later consulted in person regarding aquatic plants of the region by project team personnel on an information-gathering field trip/site visit.

E-mail consultation with Dr. Andre DeLorme, VCSU

July 13, 2001.

Dr. DeLorme was contacted regarding his ongoing work on invertebrates from the Sheyenne River and Devils Lake. He was asked if he would be willing to provide a species list, but he responded that his identifications were not being taken to the species level. He offered to provide whatever information he had when it was available. However, this information was not available early enough to include in this study. Dr. DeLorme's comments and suggestions follow:

```
Subject: Re: Sheyenne R. macroinvertebrates
Date: Fri, 13 Jul 2001 13:07:16 -0500
From: "Andre DeLorme" <Andre_DeLorme@mail.vcsu.nodak.edu>
To: <jgathman@petersonenv.com>

"...I have been working on the Sheyenne for
about 5 years focusing mainly on macroinvertebrates.  I'm also doing work on
the EIS for the Devils Lake outlet.  We are currently doing sampling along
the entire length of the Sheyenne along with some samples in Devils Lake and
Lake Ashtabula.  If you are looking for taxa lists that shouldn't be to hard
to put together.  As for past work and other people working on the biota
there isn't a lot available.  Are you familiar with a publication called
Annoted Bibliography on Aquatic Biota of Devils Lake, Sheyenne River, Red
River of the North, and Lake Winnipeg prepared by Jean Schmidt in 1999?  I
think it is an Army Corp document but I'm not sure - my copy has nothing
more than the title and author on it.  It has references to what research
has been done.  A lot on plants, fish, and periphyton, the rest is rather
scarce."
```

July 13, 2001.

Subject: Re: Sheyenne R. macroinvertebrates
Date: Fri, 13 Jul 2001 16:34:52 -0500
From: "Andre DeLorme" <Andre_DeLorme@mail.vcsu.nodak.edu>
To: <jgathman@petersonenv.com>

"Basically we are trying to document the Macroinvertebrate fauna of the Sheyenne. We are using the basic Rapid Bioassessment Protocols with a few modifications as our SOP. Unfortunately we are not attempting to go down to species for all samples at this time. We are doing genus level on most things.

"About the Schmidt bibliography - it has most of what I know about out there. I've had a several people call me about the EIS and they all comment on how little has been done. A couple of other sources that aren't in Schmidt are Dr. Marvin Fawley of North Dakota State University, who has been doing periphyton work on the Sheyenne and Devils Lake and Bonnie Alexander, another professor here at VCSU who found Eurasion water milfoil in the Sheyenne. Since Schmidt has very little for macroinverts I do have quite a bit to add to the lists."

July 27, 2001.

Subject: Re: Sheyenne R. macroinvertebrates
Date: Fri, 27 Jul 2001 15:13:39 -0500
From: "Andre DeLorme" <Andre_DeLorme@mail.vcsu.nodak.edu>
To: <jgathman@petersonenv.com>

"We are doing some collecting on Devils Lake. Mainly ponar grabs at five different locations. Not a real exhaustive study. I will be more than happy to send you a taxa list when we are done. We have done two sampling periods, one in late May and one that we are completing right now. We will do one more in September."

Summary of consultation with Dr. Marvin Fawley, NDSU

July 23, 2001.

After several e-mail exchanges, Dr. Fawley was telephoned regarding his studies of algae from the Sheyenne River. He helped to determine which of the unattributed data tables in the USACE bibliography were from his work, and explained that some data were from phytoplankton studies, while other data were from periphyton studies. He also explained that one of the tables was likely from work done by Dr. Karen Phillips-Fawley for the ND State Health Department.

<u>E-mail consultation with Dr. Robert M. Goldstein, USGS</u>

Dr. Goldstein was asked for data on Red River algae and invertebrates that he collected as part of a fish study, but chose not to include in the study reports. He mailed the reports that outlined the sampling sites and methods, electronically sent the data files, and offered comments regarding interpretation of the data. These are included as edited e-mail messages below:

<u>August 2, 2001.</u>

```
Date: Thu, 2 Aug 2001 13:20:15 -0500
From: "Robert M Goldstein" <goldstei@usgs.gov>
To: Joe Gathman <jgathman@petersonenv.com>
CC: "David L Lorenz" <lorenz@usgs.gov>
```

"I can send you a copy of our Red River fish report...
It has the methods, species, and locations of capture. I'd also suggest looking at Todd Koel's dissertation (he worked with John Peterka at NDSU), and I believe he published something on the distribution of fish in the basin also. Keep in mind that I had only two sites on the Red mainstem - downstream from Fargo, and a few miles upstream of the border. The remaining sites were scattered throughout the basin on tribs.

"As far as taxa lists of inverts and algae go, I did collect them at the same sites as the fish. However, I have reservations about those data. First, the samples sat for about three years in formalin prior to examination. Second, Several of the samples have been through a couple of id and enumerations with different results. The taxa lists generated by these exams differ enough that I'm not comfortable with them. Third, I had problems with the algae ids just in terms of presence/absence at multiple reach/ multiple year sites (three reaches sampled one year and then one reach sampled for the next two years). The variability between reaches at a site or between years at a reach is just as great as the variability among all the sites so the signal to noise ratio is about 1. That's why I haven't done much of anything with those data, and so I am hesitant to let those data be used.

"I didn't collect any zooplankton..."

<u>August 3, 2001.</u>

"The algae list is our QMH data The QMH stands for qualitative multi-habitat sample, a presence absence list.
The Invert list includes the presence/absence from additional types of samples - RTH (richest targeted habitat) and DTH (depositional targeted habitat).

"The algal ids were done by the Academy of Natural Sciences of Philadelphia and the inverts were done at the USGS National Water Quality Lab - Biological Unit. I can't really say which (whose?) taxonomy was followed. As I said I have had the same samples looked at twice and the taxonomy while similar, is not the same."

E-mail consultation with Mr. Randy Hiltner, ND Game and Fish Department

July 23, 2001.
Mr. Hiltner was contacted on different occasions for different reasons. He was first asked to provide any information on fish parasites and pathogens available to him through the NDFGD. His reply follows:

"I don't have information on fish parasites and diseases. The ND Game and Fish Dept. does not have a fish disease specialist on staff and I am not aware of any fish disease specialist in North Dakota. The only person I know that may be of some help is Dr Harry Holloway Jr., a retired Biology Professor from the University of North Dakota. Direct contact or a literature search in his name may produce some salient information."

July 24, 2001.
Mr. Hiltner was contacted regarding exotic species reports from Devils Lake. He was asked, 1. how Devils Lake fish stocking records could be accessed, and 2. whether any automatic PBOC had been reported from the lake (a list of automatic PBOC was provided). His response follows:

"You can get the information for #1 by emailing Jerry Weigel (jweigel@state.nd.us).
As for #2, to my knowledge, no common carp have been sampled or reported from Devils Lake, at least in the past decade. I don't know of any report documenting the presence of any species of concern listed in your email. As far as a contact regarding plants species at Devils Lake, possibly the university system has some current information."

September 28, 2001.
Mr. Hiltner was asked whether nuisance algal blooms had occurred on Devils Lake. His response follows:

"Over time there have been numerous blue-green algae blooms at Devils Lake (and at most of North Dakota's lakes and reservoirs for that matter). Some of the blooms resulted in isolated fishkills, most kills were minor. I'm not sure if the ultimate cause of death in these situations were from low dissolved oxygen levels brought on by algal decay and respiration and/or by cyanotoxins. From the standpoint of isolated fishkills, yes, blue-green algae has caused some problems in the past at Devils Lake and will likely continue into the future."

Consultation with Dr. Harry Holloway, UND - retired

July 26, 2001.
In a telephone conversation, Dr. Holloway was asked whether he knew of any fish parasites from Devils Lake other than those already published. He did not know of any other parasites, or published sources or experts that could provide such information.

<u>Consultation with Mr. Dennis Wright, Freshwater Institute, Fisheries and Oceans Canada</u>

Dr. Wright was consulted several times, and he provided several suggestions and names of other people to contact regarding Red River and Lake Winnipeg biota.

<u>Consultation with Dr. John Peterka, NDSU - retired</u>

<u>July 23 and 30, 2001.</u>
Dr. Peterka was asked to provide information and other contacts that could be of use for the study. He suggested many papers and experts to consult, most of which were already known to project team personnel.

<u>Consultation with Dr. Alex Salki, Freshwater Institute, Fisheries and Oceans Canada</u>

Dr. Salki was consulted several times by e-mail and telephone. He provided several reports on Lake Winnipeg plankton studies, and suggested some additional sources to consult.

<u>Consultation with Dr. Karen Phillips, ND State Health Dept.</u>

<u>August 8, 2001.</u>
Dr. Phillips was asked via e-mail whether she knew of toxic blue-green algae occurring in Lake Ashtabula. Her response follows:

```
Subject: Re: toxic blue-greens
Date: Mon, 24 Sep 2001 11:07:09 -0500
From: karen_phillips@ndsu.nodak.edu
To: Joe Gathman <jgathman@petersonenv.com>

"We have not observed Nodularia spumigena in the
periphyton or phytoplankton of the Sheyenne River or
Lake Ashtabula. We could have possibly overlooked it, if
the numbers were low. Our most prominent blue-green is
Aphanizomenon. Aphanizomenon blooms in Lake Ashtabula
from May until November and we have found it in the
Sheyenne River as far as Harwood."
```

Dr. Phillips was later consulted in person during a field trip/site visit by project team personnel seeking vascular plant information. She provided additional unpublished periphyton data from Devils Lake that were not printed in the USACE bibliography.

E-mail consultation with Mr. Terry Steinwand, ND Fish and Game Dept.

August 8, 2001.

Mr. Steinwand was asked whether he could provide any information on Devils Lake biota that was not included in the USACE bibliography. As stated below, he knew of no additional information sources. Also, at the Technical Committee meeting in Fargo on August 15, 2001, Mr. Steinwand provided information on zander and grass carp in Spiritwood Lake.

```
"...As you've already surmised, we had a
very small amount of information for reference in our earlier effort and,
although, we didn't have a great deal of time to research the subject, have
since put a bit more effort into it without result.  We garnered the
invertebrate and plant information from the ND State Health Dept. records
and the Department of Fisheries and Oceans in Winnipeg provided the Canadian
records to the best of their ability.  As for fish pathogens in Devils Lake,
there is very little available and the only possible source is Dr. Harry
Holloway, retired professor from the University of North Dakota and Dr.
Terry Dick (I believe the University of Manitoba).  I've spoken with Dr.
Holloway and there is very little information available.

We will continue our search but not with much optimism.  Sorry I couldn't be
of more help."
```

E-mail consultation with Mr. Paul Stolen, MN Dept. Natural Resources

July 19, 2001.

Mr. Stolen was asked for any information he may be able to provide on biota of Devils Lake or the Red River basin. He sent an early version of the Statement of Work, and a report from a study on recreational boaters in the Devils Lake area (Grier and Sell 1999)

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"...I worked on a scope of work which the MDNR sent
to the COE on this subject.  Send me your address and I will mail it to you.
There is also additional information that is/will be developed."
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Fish and Fish Parasite Resources: Expert Consultations

Phone consultation with Ms. Sue Marcquenski, Wis. DNR

Call by: Steve Shepard

Call to: Sue Marcquenski
Wisconsin Dept. of Natural Resources
Bureau of Fisheries Management
608.266.2871

Re: *Heterosporis sp.* in Wisconsin

Date: 2 August 2001

I called Sue to verify, and add to, the information I'd collected on the distribution and species of fish that have been infected by *Heterosporis sp.* in Wisconsin.

Sue verified that *Heterosporis sp.* has been confined to the Eagle Chain of Lakes, including Catfish Lake, in Wisconsin. She also verified that it has been common in yellow perch, and only a single walleye has tested positive.

I asked about the distribution outside Wisconsin. She said the disease was discovered about the same time in Wisconsin and Minnesota and has since expanded to more lakes in Minnesota. She said it was originally found in Leech Lake and Vermilion Lake, but she thought it has now been found in many more Minnesota lakes. She thought that since it has been found so rapidly in numerous lakes, that it either already existed there or has spread rapidly. She suggested contacting Joe Marcino (651.296.3043) for more details on the presence in Minnesota – I had already sent an email to him (no response to date). She also offered that the disease has been found Lake Ontario and suggested contacting Jim Hoyle (613.476.7677) in Ontario. She said she was not sure how it is spread – although it can be spread from fish to fish, she thought other routes (e.g., birds, bait buckets, boats, etc.) may turn out to be viable.

I noted that Hoffman (1999) lists two species of *Heterosporis* and Lom (2000) had recommended adding a third. She said Lom had authored a book (Protozoan Parasites of Fishes) that had more detail on species in this genus. She said some PCR genetic sequencing may be completed soon and help to clear up the species and source of the disease that is found in North America.

She also said that Dr. Sutherland (608.785.6982 at Wisconsin State?) had successfully cultured the disease in the lab and infected yellow perch and possibly other species.

<u>Phone Consultation with Mr. Kelly Bakken, Devils Lake bait vendor</u>

Call by: Steve Shepard

Call to: Ed's Bar, Bait and Convenience
(Spoke w/ Kelly Bakken)
701.662.8321

Re: Bait used in Devils Lake and regionally

Date: 3 August 2001

I spoke to Kelly Bakken to get some information on live fish that are used as bait in the area. He said the only live fish they currently sold as bait were fathead minnows, although in the spring they sold shiners and lake chub. The shiners and lake chub are larger fish (up to 12 inches) that are sold for several weeks specifically to anglers seeking northern pike and walleye. They also sell leeches that are trapped locally.

I asked about the source of fish and he said the fathead minnows were trapped locally in sloughs and lakes. He said it was not legal to trap bait in Devils Lake. He said the shiners and chub were bought from a local wholesale bait dealer, Fredericks Live Bait. He thought the shiners and chub might originate in Wisconsin.

I asked where the bait was used. He thought most anglers were fishing in Devils Lake, Cavanaugh Lake or Sweetwater Lake. He did not think anglers were traveling as far as the Red River drainage with bait purchased in Devils Lake. He thought anglers fishing in the Red River would be pursuing catfish and using cut bait.

<u>Phone consultation with Mr. Jerry Weigel, NDGFD</u>

Call by: Steve Shepard

Call to: Jerry Weigel, NDGFD Fisheries Production and Development Section

Re: Fish diseases among hatchery stocks

Date: 13 August 2001

I talked to Jerry about and specific instances of diseases in fish stocked in Devils Lake and in general about fish culture and disease transmission in North Dakota.

<u>Devils Lake</u>

Game fish in Devils Lake have originated both from stocking wild fish from other water bodies, and from ongoing hatchery programs. Wild stocks captured in other lakes and stocked in Devils Lake were the source of the resident stocks of yellow perch, black crappie and white bass.

Fish culture programs are the source of the walleye and northern pike that are stocked annually. Hatchery origin muskellunge were also stocked in some years, but are no longer stocked in Devils Lake. The hatchery fish stocked in Devils Lake come from either Garrison Dam National Fish Hatchery (NFH) or Valley City NFH. Garrison Dam is much larger, rears many more fish, and thus, is more often the source of fish for Devils Lake. Both hatcheries are certified as disease free and there are no known diseases among any of the cool water or warm water fish produced at these facilities. Thus, to his knowledge, no diseases had been introduced into Devils Lake via fish culture practices.

<u>General Disease Issues</u>

Some of the general fish culture practices in the midwest have a bearing on whether diseases might be transferred via stocked fish. Perhaps most important, it is very uncommon to test these fish for diseases. Unless they exhibit symptoms, it is unlikely that any warm water or cool water fish would ever be tested. According to Jerry, this is the common practice among fish culturists in the region.

As a general practice, brood stock for warm water and cool water game fish (e.g. largemouth bass, walleye, northern pike, and muskellunge) programs come from the wild. That is, brood fish are captured annually at a convenient location. For example, in some years, Devils Lake was the source of brood stock for fish that were cultured and stocked all over the state, including rivers and lakes in the Hudson Bay drainage. Thus, there are historic transmission routes whereby any diseases that might be in Devils Lake fish could have reached locations all over the state, including the Hudson Bay drainage.

Movement of game fish throughout the state is a common practice. In the example above, warm water and cool water species come from one water body as brood stock, are reared in a hatchery, and then may be stocked anywhere. The same is true of cold water species (trout and salmon) except that the brood stock usually originates from captive sources. For example, the Garrison Dam NFH rears most of the trout and salmon stocked in North Dakota. According to Jerry, the species reared include chinook salmon, rainbow trout, brown trout and cutthroat trout. Brood stock typically come from captive stocks held at various federal hatcheries, some being outside North Dakota. These cold water fish are then reared at one of the hatcheries and then might be stocked anywhere. Some of the diseases on our list of PBOC (i.e., *Myxobolus cerebralis, Renibacterium salmoninarium,* and infectious hematopoietic necrosis virus) are much more common among salmonids. Including potential cross-contamination within the hatchery facilities, there are potential routes of disease transmission to/from Devils Lake from virtually anywhere in North Dakota and some out-of-state areas. The issue of disease transmission via water transfer seems to be rather moot.

<u>Phone consultation with Dr. Terry Dick, U. Manitoba</u>

Call by: Steve Shepard

Call to: Dr. Terry Dick
University of Manitoba
204.474.9896

Re: Fish Parasites *Rhadinorhynchus sp.* and *Gyrodactilus hoffmani*

Date: 19 September 2001

Dr. Dick said he was not aware of any Acanthocephalan worm in the genus *Rhadinorhynchus sp.* ever showing up in the Hudson Bay drainage. We talked about this genus and related fauna. I told Dr. Dick that, according to Hoffman (1999), this is a marine genus that shows up in anadromous fish in the north Pacific, and sometimes in *Oncorhynchus sp.* in freshwater. This was his understanding as well, it was more of a marine fauna and he said he could not imagine how it might have gotten into Devils Lake.

I said there were only two species shown in Hoffman (1999), but 15 were listed in a 1985 reference (Crompton and Nickol, 1985). I asked him if there were taxonomic changes since 1985 and if it was possible that what was correctly identified as *Rhadinorhynchus sp.* in Devils Lake in 1981 has been changed to another genus. He did not think this was the case. Rather, he thought the two species shown in Hoffman (1999) were freshwater species and there may even be other species that Hoffman may have missed. He thought it was more likely that the *Rhadinorhynchus sp.* in Devils Lake was misidentified. He said that Acanthocephalans in the genus *Leptorhynchoides* were quite common in the northern prairie states and the Hudson Bay drainage and it is quite likely that this is what it was. (Note: *Leptorhynchoides thecatus* is listed for the lower Sheyenne River.)

I asked him about the occurrence of *Gyrodactilus hoffmani* in Canada. Dr. Dick said he was not aware of this species in Canada. I told him that the information I have only lists fathead minnow as a host. He said that all the Gyrodactylids are somewhat host specific. He has not looked at the parasites of minnows very often. Thus, he thought that it may be present in Canada but not yet identified.

Before letting him go, I also asked about the occurrence of *Ligula intestinalis*. He verified that this has a ubiquitous distribution in Canada. He said that wherever piscivorous bird reside, particularly nesting locations, this worm is found.

Phone consultation with Mr. Joe Marcino, MN DNR

Call by: Steve Shepard

Call to: Joe Marcino, Pathologist
Minnesota Department of Natural Resources
651_296_3043

Re: Fish Parasites *Rhadinorhynchus sp., Gyrodactilus hoffmani,* and *Ligula intestinalis*

Date: 19 and 20 September

I called Joe on two occasions to discuss fish parasites. He was unfamiliar with Acanthocephalan worms in the genus *Rhadinorhynchus.* We discussed my conversation with Terry Dick (see telecon of 9/19) and he agreed that it seemed more likely that the *Rhadinorhynchus* was a misidentified *Leptorhynchoides*, probably *L. thecatus.* He said it seemed extremely unlikely that *Rhadinorhynchus* was actually present in North Dakota.

I asked Joe about *Gyrodactilus hoffmani.* He was quite sure this was widespread in Minnesota, including the Red River of the North.

I also asked him about *Ligula intestinalis*. He said this was also quite common in the region. He agreed it would be found wherever piscivorous birds were found.

Phone consultation with Mr. Walter Lysack, Manitoba Conservation, Fisheries Branch, Sport & Commercial Fishing

Call by: Leigh Morgan, David Miller Associates

Call to: Walt Lysack
Manitoba Conservation
Fisheries Branch
(204) 945-6640

Re: Lake Winnipeg fishery

Date: January 24, 2002

Mr. Lysack reported that no sport fishery studies have been done for Lake Winnipeg. The sport fishing is not very desirable because the lake is very shallow and "comes up" quickly. Sport fishing is very popular at Grand Rapids and in the Dauphin River, but not on Lake Winnipeg. He said that commercial gill net fishing is the primary pressure on the fishery.

Phone consultation with Mr. Gene VanEechout, ND DFG

Call by: Steve Shepard

Call to: Gene VanEechout, North Dakota Dept. Fish and Game
701 253-6482

Re: Lake Ashtabula

Date: 14 Jan 02

I discussed Lake Ashtabula fisheries and habitat with Gene, the regional biologist for that part of North Dakota. He confirmed, and expanded upon, some fisheries information I had already found from some NDFG and USACE documents on the web, namely:

The major fisheries are walleye, northern pike, yellow perch, white perch, and bullhead. According to Gene, there is no significant reproduction of walleye and northern pike. About 104,000 walleye fingerlings are stocked annually About 219,000 northern pike fingerlings have been stocked annually. Gene noted that no northern pike were stocked last year in response to changing angler preferences. Yellow perch, white perch, and bullhead are maintained by natural reproduction although some yellow perch were stocked in 1996. The yellow perch fishery was the best in the state but has declined somewhat in recent years. Lake Ashtabula supplies brood stock to much of the state via the nearby Valley City NFH and the satellite facility at Baldhill Dam.

We discussed lake morphology, water quality, and habitat. The relevant points of our discussion are as follows:

Approximate dimensions of the lake are 5,200 acres in size, 27 miles long, with about 78 miles of shoreline. Two bridges/causeways divide the lake into three sections. Sedimentation is rapidly filling in the reservoir from upstream to downstream. The upper basin has filled significantly since the reservoir was formed. The average depth is about 13 feet, with a maximum depth of about 45 feet near Baldhill Dam.

The lake is eutrophic to hyper-eutrophic. It is on the EPA list of impaired waters and a high priority for TMDL development (EPA web site). Maximum summer temperatures are generally in the mid 70’s. The waters are generally well mixed in summer due to wind. The lake does not stratify during open water periods. Thus, dissolved oxygen is generally adequate for aquatic life during open water. The lake may stratify during winter due to ice cover and very low inflow. There may be some dissolved oxygen depletion during winter. Gene thought this had occurred in the 1970’s.

The lake is drawn down 5-10 feet in late winter and refilled during spring runoff for flood control. Spring runoff is extremely turbid with high sediment loads. Sediment deposition appears to inhibit aquatic plant development. Sediment loads and deposition smother northern pike eggs and prevent reproduction.

The lake is primarily warm-water habitat with extensive shallow areas in most of the lake.
Annual draw down exposes large areas of the bottom and returns many miles of the reservoir to the original stream channel. The river upstream of the reservoir is a meandering channel with deep water and fine substrates. The first riffles upstream of the project are about 20-25 miles upstream. Although the walleye population is maintained by stocking, walleye are known to make spring spawning migrations to the upstream riffle habitat. Some walleye reproduction may occur there. Recent oxytetracycline marking of hatchery walleye should provide data on the extent of any natural reproduction.

Based on the information I have, I suggested to Gene that juvenile striped bass might survive and grow in the reservoir. It is significant that it supports white bass and walleye – species with similar lacustrine habitat requirements. Although the reservoir does not have the type of prey favored by striped bass (clupeids), and it does not stratify, it has an appropriate thermal regime. Alternate prey might include juvenile white bass and minnows. Competition would likely occur with the other piscivorous species (walleye and northern pike). Gene agreed that these are reasonable conclusions.

We discussed striped bass reproduction. Gene said that he did not have expertise in striped bass reproduction. I told Gene that the few freshwater systems that support striped bass reproduction have much larger inlet rivers and that striped bass spawning habitat is found exclusively in riffles in these large rivers. In general, striped bass require large volumes of fast water and hard substrates and will migrate many miles to reach these habitats. Eggs and larvae must remain suspended. Gene felt these conditions are not present in the Sheyenne River in the spring. I noted that mean April flows ranged from less than 100 cfs to just over two thousand. Thus, the Sheyenne does not appear to have sufficient volume. In addition, the high suspended sediment loads may result in egg or larvae mortality.

Phone consultation with Mr. Chris Hayes, CA DFG
Branch, Sport & Commercial Fishing

Call by: Steve Shepard

Call to: Chris Hayes, Cal. Dept. Fish and Game
760 922-6508

Re: Colorado River striped bass

Date: 11 Jan 02

I discussed striped bass populations of the Colorado River with Chris for some time. He informed of the following.

- Naturalized striped bass populations have become established in four reservoirs; Lake Mead, Lake Powell, Mohave Lake, and Lake Havasu.
- In addition, juveniles or eggs are entrained in the pumps of the California State Water Project and transferred to several downstream water bodies, where they grow and provide a fishery, but do not reproduce.
- Threadfin shad are the primary prey item in all reservoirs.
- Several of these reservoirs have become overpopulated with striped bass and, as a result, individuals are stunted, the threadfin shad are scarce, and alternate prey (e.g., juvenile largemouth bass) are used.
- All the reservoirs are stratified with cool, well oxygenated hypolimnion waters.
- Spawning reaches are large, fast moving, main stem, riffles.
- Reproduction requires that water velocity is sufficient so that the eggs remain suspended until hatching.
- Reproductive success varies between the reservoirs and some downstream populations may be supported in part by drift (juvenile entrainment) from upstream reservoirs.
- The larger Lake Mead has a retention time of about 5 years while Lake Havasu exchanges water about every three months.